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NAVPERS 93373

INTRODUCTION TO FIRE CONTROL

TRAINEE'S GUIDE

for

FIRE CONTROL TECHNICIAN TRAINING

STANFORD UNIVERSITY
MAY 1966
GOV'T DOCUMENTS DIVISION

MARCH 1966

(1)

BUREAU OF NAVAL PERSONNEL

(2) NAVY

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE NAVY
BUREAU OF NAVAL PERSONNEL
WASHINGTON, D.C. 20370

20 January 1966

INTRODUCTION TO FIRE CONTROL
TRAINEE'S GUIDE
NAVPERS 93373

1. This publication and the companion Instructor's Guide, NAVPERS 93372 are the approved curriculum for the "Introduction to Fire Control" block of instruction in Navy Fire Control Technician Schools, Class "A", and are effective upon receipt.

2. Corrections and recommended changes to this publication are invited. Commanding Officer, U. S. Naval Schools Command, Mare Island, Vallejo, California, 94592, has been assigned clearing house responsibility for evaluating and compiling recommended improvements, and for submitting them to the Chief of Naval Personnel in the form of a proposed change to the publication. Users of this course material are requested to submit their recommendations directly to the command having clearing house responsibility, with a copy to the Chief of Naval Personnel (Attn: Pers-C12). No deviations from this curriculum are authorized until approved by the Chief of Naval Personnel.

3. This publication does not supersede any existing publication.

G. M. METZE, Captain, USN
Director, Weapons Systems and
Fleet Training Division

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SAFETY NOTICE

WARNING

The attention of all hands is directed to Section V, Chapter 67 of Bureau of Ships Technical Manual or superseding instructions on the subject of safety.

Dangerous voltages are employed in the training devices and equipments used throughout this course. Contact with live circuits can result in permanent injury or death.

NEVER MEASURE POTENTIALS OVER 600 VOLTS BY MEANS OF FLEXIBLE TEST LEADS OR PROBES.

DO NOT SERVICE OR ADJUST ALONE:

Under no circumstances should any person work on live equipment without the immediate presence or assistance of another person capable of rendering aid.

DO NOT TAMPER WITH INTERLOCKS

NOTES

(A) MAKE SURE you are NOT GROUNDED whenever working near or using test equipment on live circuits.

(B) In general, USE ONE HAND only when working around live circuits.

(C) ALWAYS ground the metal case of test equipment before using.

(D) DO NOT FORGET that high voltages MAY BE PRESENT across terminals that are normally low voltage due to component breakdown or equipment malfunction. Use care even when measuring low voltages.

(E) NEVER USE electrical or electronic equipment known to be in poor condition.

(F) ALWAYS inspect test leads, line cords, etc., to insure that no cracked or broken insulation, frayed wires or loose connections exist, before using any portable electrical or electronic equipment.

(G) High-voltage, high-capacity capacitors should be discharged with a suitably insulated shorting or grounding bar with about 10 ohms in series with the grounded line. Where neither terminal of a capacitor is grounded, short the terminals to each other.

RESUSCITATION

Approved posters illustrating the correct procedures and listing rules for resuscitation must be displayed prominently in each fire control, radio, radar, or sonar enclosure. These posters may be obtained upon request to the Bureau of Medicine and Surgery. Formerly, manual methods of artificial respiration were used exclusively. These methods include the prone pressure method, the hip lift-back pressure method, the arm lift-chest pressure method, the arm lift-back pressure method, and Eve's method (rocking on a stretcher). More recently, the "rescue breathing" methods have come into prominent use. These latter methods represent the most efficient means of resuscitation without the use of special equipment, and include mouth-to-mouth, mouth-to-nose, and mouth-to-mouth-and-nose techniques.

Mouth-to-mouth resuscitation is accomplished by sealing one's mouth over the patient's mouth, pinching the nostrils shut, and blowing until his chest lifts—an indication that his lungs are filled with air. The air is then allowed to escape, and the procedure is repeated at the normal rate of breathing until the patient can breathe for himself.

Resuscitation using the patient's nose for an airway is as satisfactory as the mouth-to-mouth method. It is the method preferred by many. When this method is used, the patient's mouth is held closed as air is blown into the nose.

Both the nose and mouth may be used as the patient's airway. This method is, in fact, quite often used when administering resuscitation to infants.

SUMMARY OF STEPS USED IN RESCUE BREATHING:

1. Start the process immediately.

2. Place the patient on his back.

3. Clear the mouth and throat of debris.

4. Tilt the patient's head back.

5. Pull the patient's chin forward, using the middle fingers, so that the lower jaw is literally lifted and it "juts out". This step is necessary to keep the tongue out of the air passage. The lifting is accomplished by placing fingers beneath the jawbone and behind it on a line almost perpendicular to the ear. Using one hand, hold the jaw in this position.

6. Blow air through mouth or nose (or both) until chest rises. (Nostrils should be pinched with fingers if mouth-to-mouth method is used.)

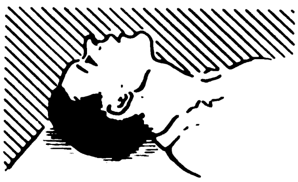
7. Remove your mouth and listen for snoring and gurgling—signs of throat obstruction. If the throat is obstructed, turn the patient quickly on his side and administer several blows between the should blades in an effort to dislodge the obstruction.

8. The complete cycle of filling the patient's lungs with air and allowing them to deflate should be smooth, with each complete cycle starting at approximately five-second intervals.

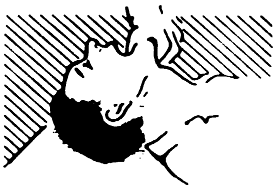
9. Continue rescue breathing until the patient breathes for himself.

Although rescue breathing is the preferred method for administering artificial respiration, the technician should be skilled in other methods in order to manage situations where rescue breathing cannot be used. The method to be used is dictated by the condition of the patient, the availability of equipment and trained personnel, and the particular environment.

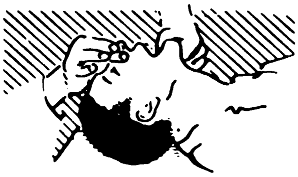
There are procedures applicable to all methods of resuscitation. The first thing is to begin immediately by putting the patient in the proper position. DO NOT WAIT FOR HELP OR EQUIPMENT. Since every second counts, start the resuscitation and attend to secondary measures as you proceed. The important thing is to establish and maintain the rhythm of artificial respiration without interruption. Matters such as clearing debris from the mouth, pulling out a swallowed tongue, keeping the area about the mouth clear so that no foreign matter is taken in, loosening clothing which restricts breathing, removing wet clothing and keeping the patient warm are vital, but they should be done without interrupting the rhythm.



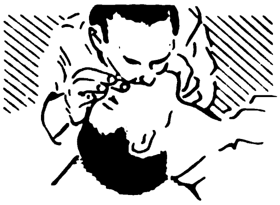
Thrust head backward.



Lift tongue and jaw.



Pinch nostrils.



Blow into patient's mouth.

The patient should not be given any food or liquid until he is fully conscious. The artificial respiration should be performed on the scene if possible. Once breathing is restored, the patient should be transported on a stretcher for further medical attention.

HOW TO USE THIS TRAINEE'S GUIDE

PUBLICATION

This Trainee's Guide has been prepared for use in Navy Fire Control Technician Schools.

TRAINING GOALS

This course material is divided into sections which are further divided into topics. The training goals are stated at the beginning of each topic, with a brief outline of the discussion points to be covered by the instructor.

STUDY ASSIGNMENTS

Self-study assignments serve to supplement classroom instruction. The trainee is urged to reinforce his knowledge by reading study assignments during class study periods or when otherwise scheduled by the instructor.

QUIZ SHEETS

A Quiz at the end of each section is to be completed as directed by the instructor. Do not mark this book - write your answers on a separate sheet of paper.

SAFETY PRECAUTIONS

Read the SAFETY NOTICE carefully. Develop safe working habits and practice safety always. Take time to be safe.

RECORD OF CHANGES

Number or Description of Change	Made by	Date

Section 1

YOUR FUTURE IN FIRE CONTROL

Topic No.	Topic Title	Page
1.	The Fire Control Technician	2
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TOPIC 1: THE FIRE CONTROL TECHNICIAN

YOU ARE NOW GOING TO LEARN:

1. What an FT is.
2. The history of fire control.
3. Fleet duties of an FT.
4. Paths of advancement.
5. Scope and objective of FT school.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Definition of fire control.
2. Reason for selection.
3. FT's creed.
4. History of fire control.
5. Fleet duties of an FT.
6. Paths of advancement.
7. Scope and objectives of FT school.
8. Review and summary.

INFORMATION AND DISCUSSION:

DEFINITION OF FIRE CONTROL

The purpose of this topic is to introduce you to the rating for which you have been selected. The words "Fire Control" mean the directing of various weapons so that they will hit the desired target. As you learn about fire control, you will realize that the Navy is only as strong as its fire power and in order for its fire power to be effective, it must be accurately controlled. That is where you, as a Fire Control Technician, play a vital part in making your ship an effective weapon against enemy ships, planes, submarines, and shore installations. It will be your job to operate and maintain the many complex devices used in your ship's various fire control systems.

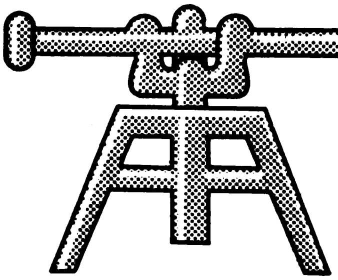
REASON FOR SELECTION

What kind of men make good Fire Control Technicians? What kind of mental equipment do you need to make the grade? Before the Navy approved you as a striker for FT3, it gave you a battery of tests. Because you passed those tests and got exceptionally high marks, we know you have the ability to learn quickly, and to master a large body of technical knowledge. Also, you have mechanical aptitude; if you haven't already developed a high degree of mechanical skill you have what it takes to acquire it.

Besides the occupational or professional duties, you will have certain military duties, as do all ratings in the Navy. These military duties include the manning of battle stations, watch standing, and other assignments related to the requirements for naval operations, management, and security. In order to become a valuable Fire Control Technician, you will need other things besides a sharp brain and skillful hands. You must be conscientious and completely reliable. A Fire Control Technician is exemplified by his creed.

HISTORY OF FIRE CONTROL

Although cannons have been in use for many centuries, fire control in anything approaching its present form is comparatively new. Prior to about 1800, guns were not even equipped with sights, and it may be said that no form of fire control existed. Naval gunnery at that time depended upon bringing the guns as close to the enemy vessel as possible and literally firing muzzle to muzzle. Frequent ranges of the period were "half pistol" and "pistol" shots, from 20 to 50 yards. Sighting consisted of laying the guns in azimuth, and leveling them by eye, sometimes allowing for the curvature of the trajectory by "sighting by the line of metal", i. e.; bringing the top of the breach and the top of the muzzle in line with the point of aim, which caused the gun to be elevated by the amount of taper of the gun. Practically



FIRE CONTROL TECHNICIAN'S CREED

I am . . . a Fire Control Technician, a line petty officer in the United States Navy. My prime responsibility is the repair, maintenance, and operation of Fire Control equipment on the fighting ships of the fleet.

I am a trained specialist . . . a technical assistant in the Weapons Department of my ship, I am not a machinist mate, electronics technician, or instrument man, but I must be able to perform the duties of these skilled specialists in order to maintain the complex electronic, electrical, and mechanical equipment required to compute and resolve the many factors which influence the accuracy of our Navy's offensive and defensive weapons afloat.

My aim . . . is to know my job. To achieve this goal, I must know, as thoroughly as possible, everything that pertains to practical gunnery and ordnance. As long as I do not understand the operation and maintenance of every component and system of Fire Control equipment, my job is not complete.

As the fortunes of war are various, I must be capable of performing any operation and be competent to man any station in the Weapons Department of my ship. In addition, I will endeavor to know maintenance duties so well that the battle efficiency of my ship may always be sustained at the highest level, even on a darkened ship under enemy attack. This . . . to the end . . . that the shells, missiles, rockets, torpedoes, and depth charges may find their mark, as long as the ship is afloat.

no attempt was made to account for the initial velocity. Powder charges were estimated and the projectile load would be one shot or several shots. At close range, guns were loaded to the muzzle with grape shot.

The British and French navies began using pendulums to regulate the position in which ordnance should be laid, with reference to the angle of heel, so as to produce a fire nearly horizontal. The practice was to suspend one of these instruments in an open hatchway and circulate orders to elevate the lee guns or depress the weather guns, depending on how the ship was engaged. This procedure was considered so important, and justly so, that the indications of the pendulums were compared and checked with reflecting instruments, so constructed to show by coincidence of real and reflected horizons the instant in which the axis of the guns were horizontal. This combination, called "L Horizon Ballistique" is mentioned in several texts as an important discovery.

Gun sights, as first introduced early in the nineteenth century, consisted of a fixed front and rear sight point, adjusted so that the line of sight across their points was parallel to the bore of the gun. The first adjustable rear sight was introduced by a French army officer and graduated in cable lengths. As late as 1864, there was still a tendency to employ the primitive method of sighting "by the metal". It was apparent that no real progress in fire control had been made. Even by the end of the Civil War, battle ranges remained so short there was no true need for fire control.

Developments in cannons and powder during and after the Civil War resulted in such greatly increased ranges and accuracy of guns, that graduated gun sights became a necessity. Sight design was improved by fitting a movable leaf in the rear sight. This leaf was adjustable both vertically and laterally. The introduction of the rifled gun with its consequent drift of projectile, brought forth sights which automatically made an approximate allowance for drift by inclination of the rear sight bracket.

The next outstanding development in fire control was the telescopic sight. Although such a device was introduced into the British army as early as 1875, it was many years later before the idea was adapted in naval gunnery. During 1890-1896, Lt. B. A. Fiske, USN, adapted a telescopic sight for attachment to the gun slide in such a manner as to compensate for speed and drift as well as for elevation and range.

With the introduction of sights that made reasonably accurate pointing possible, fire control became a science. The effects of firing vessel and target motions were investigated and provisions made for off-setting the line of sight laterally to allow for these effects in deflection. Elevation scales were graduated in accordance with data determined at proving grounds, and powder charges were carefully regulated as to weight and index.

A new era in gunnery was born early in our century when exceptional activity in improvement of fire control methods was inaugurated by a group of British and American naval officers on the Asiatic station. Some years later, about 1907, one member of the group, the late Admiral W. S. Sims (then Lt.), against strong opposition, succeeded in having adopted the first systematic, scientific, competitive target practice system. Competition created widespread interest among officers and gun crews, and caused the application of new methods to improve the ship's score. Much of the rapid progress that followed can be attributed to the introduction of the system.

During 1901-1910, many new fire control features were introduced. Among the more important of these were: the modern coincidence type of range finder, rate of change of range projectors, range clocks, plotting and tracking boards, visuals for transmitting range and deflection, voice tube and telephone communication systems, etc. Many of these important developments were the result of individual enterprise by young officers and often first came into use in the form of home-made devices or makeshift arrangements.

The next development, and perhaps the farthest reaching of all, was the introduction of a system whereby the actual laying in elevation, training, and firing of all guns of a single battery could be controlled from a single, advantageously located position.

This method came to be known as "director firing". Captain P. Scott, RN, pioneered in the bringing about of this advance. The British navy experimented with director firing between 1910 and 1912. Complete director systems were soon being manufactured by the British firm, Vickers, Ltd., and installed in British ships. Although credit for introducing director in its modern form undoubtedly belongs to Captain Scott, some use had been made of the principles of director fire at least 50 years earlier.

The USN experimented with director firing as early as 1913. A system of director control for main battery elevation, differing considerably in design from the British type, was installed on our capital ships in 1915. Director control in train soon followed.

During these years, another major advance in our Navy was the introducing of the Ford rangekeeper. This instrument collected into one mechanical unit the various functions of the rate of change of range projector, the rate clock, the plotting and tracking board, and deflection computers; it also handled automatically some parts of the problem of determining the range ballistics. By the time our battleships sailed overseas in 1917 to join the British Grand Fleet, they had been equipped with director control in both elevation and train for the main battery, and with Ford rangekeepers.

We still had no system of director firing for broadside batteries. During the war, the British Vickers system was made available to us, but installation had been accomplished on only a few ships before the armistice. Eventually our Navy had the Vickers system installed in the secondary batteries of all battleships and most destroyers. It was 1923 before the first American designed broadside director was completed and installed in the battleships of the Maryland class. A director system for anti-aircraft batteries was developed about 1926, and installed in ships having 5"/25 caliber anti-aircraft batteries.

Advances in fire control science quickly increased the ranges of effective gunfire. During the days of sailing vessels, engagements were usually fought at extremely short ranges, often yardarm to yardarm. The bloody "Chesapeake and Shannon" battle took place mostly at a range of less than 50 yards. Smooth-bored muzzle loaders occasionally were fired at close quarters. In the Monitor and Merrimac engagement, the latter vessel is said to have landed the first shot on the deck of the other from a reported distance of one mile. Practically the entire engagement, however, was conducted within about 100 yards.

Even as late as 1864, the mean battle range was considered to be about 1500 yards. At "Tsushima" in 1905, the range varied between about 4000 and 6000 yards. By 1910, our Navy was holding battle practices at 12,000 yards with reasonable accuracy. At the "Dogger-Bank" engagement, early in 1915, the opening range was between 18,000 and 20,000 yards, and at the end of World War I, fire control was efficient enough to cope with the maximum ranges possible at the elevation of 15 degrees to which our turrets were then limited (about 24,000 yards). Turret gun elevations were subsequently increased to at least 45 degrees, with ranges of 30,000 yards.

The period between 1920 and 1940 brought the fastest and most sweeping changes in fire control. Anti-aircraft fire was becoming increasingly important and great developments were made in that field. The advent of the modern director system was started and advanced during this period, as was torpedo fire control. The Mk 19 Gun Director was developed, followed by the Mk 33 Gun Director which had a stereo range finder, a Ford Rangekeeper Mk 10, and a Mk 2 Stable Element, all of which were an integral part of the director. This system was effective for use against the aircraft used prior to and during most of World War II. It could track and effectively compute data for aircraft with speeds up to 300 knots.

The next major development was the Mk 37 Gun Director, with the Mk 1 Computer and Mk 6 Stable Element. The Mk 33 and Mk 37 were the two main directors for anti-aircraft fire control at the outbreak of World War II.

The next and most far reaching improvement was radar. The fire control radars were installed in fleet units during the years 1942 and 1943. The flexibility of fire control increased a hundred-fold with these units. With radar it was possible to track aircraft at night and during poor visibility. Radar brought targets under fire under all conditions.

During World War II, to offer wider anti-aircraft protection to ships under attack by many aircraft at once, it was necessary to split the anti-aircraft battery. So that each gun or combination of guns would still have the added accuracy afforded by director control, light weight, auxiliary directors were developed.

The first of these was the Mk 51 Director which had a lead computing gunsight utilizing gyros to measure the proper lead angles. The operator added estimated range and range rate of the target.

The Mk 51 was followed by the Mk 52 Director. The Mk 52 also had a gunsight mounted on a handle-bar director but included a radar for measurement of range and range rate. The difficulty with this system was that, as the gunsight developed lead angles, the radar antenna, which was mounted on the director, was pulled off target. It was necessary for a man to manually reposition the antenna back to the line of sight. This system also had no provisions for designation of the target, night acquisition, or night tracking.

Next in the director family was the Mk 63 Director. This again was a light director with a lead computing sight but now the radar antenna was mounted on the gun and was repositioned automatically to the line of sight by a servo system. The Mk 63 system also had provisions for target designation, night acquisition, and limited radar tracking in train and elevation. The Mk 63 system is still in wide use on even the most modern of Navy ships. It has been modernized and has a newer more accurate radar but the methods of tracking and computing lead angles are basically the same.

Another Gun Fire Control System (GFCS) developed and used during World War II was the Mk 57. This system used a slightly different principle for arriving at the proper lead angles and gun orders. In the GFCS Mk 57, the director was again a handle-bar type with the radar antenna mounted on the director. The approach to the computation of lead angles was different in that instead of a gunsight which caused the operator to position the director in the line of fire, with the accompanying necessity of recovering this lead angle from the radar line of sight, the director and radar antenna remained in the line of sight. The values of sight angle and sight deflection necessary to position the gun to hit the target were computed by a gyro type computer mounted on the director and transmitted to a below-decks computer that added these values to director train angle and director elevation angle. This below-decks computer also computed the fuze setting to be applied to the mechanically timed fuzes often used with 5"/38 caliber dual purpose guns.

These directors and gun fire control systems were all first developed and used during World War II. The next gun fire control system to appear upon the scene was first introduced in the fleet shortly after World War II. It represented a great advance over all previous systems in its ability to combat all types of aircraft, including high speed targets. This was, and is, the GFCS Mk 56. No longer did we use the handle-bars; no more half measures of radar tracking. The Mk 56 system was designed from the ground up as an automatic tracking, all weather, blind acquisition and tracking, high speed, high performance gun fire control system that would last for years as an extremely valuable part of our Navy's fire power.

The Mk 56 is today still one of the mainstays of our fleet's weapons systems. This system uses gyros in the director to compute the angular rate of director movement and to stabilize the fire control problem or correct for roll and pitch about the line of sight. A modern, highly accurate fire control radar and advanced analog computers complete the system. The Mk 56 is highly reliable for AA fire on targets in the sub-sonic speed range. It also has surface fire capabilities. Although the system was designed to be an auxiliary system for splitting the AA battery, on many ships of today it represents the main battery fire control system.

All of these systems and directors, from Mk 51 to Mk 56, were originally designed to control smaller AA guns; however, they are also equipped, in some modifications, to handle all purpose guns from 40 millimeter machine guns to 5"/54 caliber rapid fire guns.

In 1945 a study program was initiated to improve the fleet air defense using existing gun systems. Improved aircraft performance and lack of a system to coordinate gun fire on the attacking aircraft had caused a major problem in the closing years of World War II. From this program came the various Target Designation Systems (TDS) such as TDS Mk 5. These systems provided a means to coordinate the gun fire control by designating a particular target to a gun fire control system. It was soon apparent that aircraft speed and performance exceeded gun capabilities, therefore attention was shifted to guided missiles for air-defense.

By definition, a guided missile is an unmanned vehicle that travels above the earth's surface; carries an explosive warhead or other useful payload, and contains, within itself, some means for controlling its own trajectory or flight path.

The principle of rocket propulsion has been known for nearly 2000 years. In the far east, rockets were used in warfare as early as the 13th century. Several western armies used rocket projectiles in the early part of the 19th century. Early use of rockets was probably of more use to frighten the enemy than to do physical damage. Military interest in rockets lapsed after the middle of the 19th century because developments in gunnery made gun projectiles superior to rockets in range, and far superior in accuracy. The present use of missiles could not, however, have reached the present point of development without much early experimentation. Our latest missiles are based also on developments in many other fields, including mass production techniques, metallurgy, aerodynamics, radar, and electronic computers.

PROPULSION SYSTEMS - In France, in 1909, Guillaume outlined the basic theory of turbo-jet propulsion. In 1927, the Italian Air Ministry built and tested a plane driven by a form of mechanical jet propulsion. In 1923, Campini, an Italian, designed and flew the first plane powered by a thermal jet. It differed from modern jets in using a piston engine, rather than a turbine as a compressor. In England, in 1930, Frank Whittle patented a jet engine based on the principles used in modern jet aircraft. The first successful flight of a turbo-jet powered aircraft was made in England in 1941.

The pulse-jet engine uses the forward motion of the missile or aircraft, rather than a turbine, to compress air and fuel vapor before combustion. The pulse-jet principle was patented by a German engineer in 1930, and further developed by Bleeker, an American, in 1933. The pulse-jet was much improved and used by the Germans to power their V-1 guided missile during World War II.

The ram-jet also depended on the forward motion for compression but it differs from the pulse-jet in having no moving parts. The basic idea of a ram-jet was patented by Rene Lorin, a French engineer, in 1913. This was followed by a Hungarian patent in 1928, and by another French patent, by Leduc, in 1933. None of these patents resulted in a workable ram-jet engine. The basic ideas were sound; but successful development of a ram-jet engine had to wait for extensive data on the behavior of fluids at extremely high speeds. In June of 1945, the Applied Physics Laboratory of Johns Hopkins University made the first successful ram-jet flight, in the course of developing a power plant for the Navy's Talos missile.

Turbo-jets, pulse-jets, and ram-jets all depended on the presence of air for the combustion of their fuel, consequently, none of them can operate beyond the earth's atmosphere. Rockets, on the other hand, carry their own source of oxygen for combustion; and they operate even more efficiently in a vacuum than they do in air. Rocket-propelled vehicles are capable of flight to the moon and the planets.

Among rocket engineers, Robert H. Goddard is known as the "Father of Rocketry". Goddard was born in Massachusetts in 1882. By the time he earned his BS degree in 1908, he was obsessed by thoughts of rockets and rocket propulsion. He believed, quite correctly, that rocket propulsion would be the most suitable means for sending measuring instruments to the top of the earth's atmosphere, and eventually to the moon. Up to that time, no one had investigated the physics of rocket propulsion, and no one had worked out the necessary mathematics. Goddard decided to do both.

Goddard was given a Navy commission in 1917 and assigned to the job of improving the Navy's signal rockets. This assignment enabled him to continue his development of rocket theory. After the war, he summarized his theories and experience in a paper called "A Method of Reaching Extreme Altitudes". This report, published by the Smithsonian Institute in 1920, consisted almost entirely of equations, formulas, and tables, but it contained one statement of general interest. It proposed the idea of multistage or step rockets, that is, one rocket carrying another, and said that by this means a rocket could be sent to the moon.

During the twenties and thirties, Goddard continued his experiments while teaching physics at Clark University. He was the first to suggest a liquid-fueled rocket and in March of 1926 the first to actually launch a successful liquid-fueled rocket. He was the first to fire a rocket that traveled faster than sound, the first to develop a gyroscopic steering mechanism for rockets, and the first to use vanes in the jet exhaust stream for stabilization. Because of the lack of funds, Goddard was forced to end his experiments in 1935, however, during World War II he again worked for the Navy to develop rockets to aid the take-off of the Navy's flying boats.

A group of rocket enthusiasts, inspired by Goddard, formed the American Rocket Society in 1930. During the thirties they performed a number of important experiments but the work was limited in scope by the lack of money.

Herman Oberth, a German counterpart of Goddard, also worked on the physics and mathematics of rocket propulsion. Except for a science fiction book in 1870, Oberth's book, "The Rocket into Interplanetary Space", published in 1923 was the first to express the idea of artificial satellites orbiting the earth.

The German "Society for Space Travel, Inc." was organized in 1927, with Oberth as president and Willy Ley as vice president. The society performed many experiments with liquid-fueled rocket engines. One of these systems was later used in the German V-2 missiles.

In 1932 the Germans established a small research project under direction of Captain (later General) Walter Dornberger, to develop liquid-fueled rockets for use as weapons. A member of the German rocket society, Wernher von Braun, was hired by the army to work on this program. In December 1934 they successfully fired two rockets to a height of about 6, 500 feet. In 1936 General von Fritsch visited the test range. The General was impressed and the result was a new and bigger research institute—the Peenemunde Project.

GUIDANCE SYSTEMS - During World War I, the Americans developed a flying bomb called the Bug. It was simply a pilotless aircraft with a range of about 400 miles. The Bug was ready for production by 1918 but never produced. In 1924, the Army and Navy both experimented with radio controlled aircraft but the project was dropped in 1932 for the lack of money.

In 1935, an American high school student named Walter Good built and flew a radio controlled model airplane. This was the first record of a plane being completely controlled from the ground.

The Army and Navy resumed their experiments with radio command during the late thirties, and by 1940, both had developed radio controlled planes for use as target drones.

GUIDED MISSILES IN WORLD WAR II - During the war, the Japanese developed and used two devices of interest in the history of guided missiles. One of these was an air-launched, radio controlled, rocket assisted, glide bomb. Its performance was limited. It had to be launched from a plane which was highly vulnerable to anti-aircraft fire, especially after we began to use the proximity fuze. The Japanese dropped this project before the end of the war.

The second Japanese missile was the baka bomb. This was a rocket propelled glide bomb designed for use against shipping. It carried a human suicide pilot; and for this reason we cannot call it a true guided missile. The baka bomb had poor maneuverability, and because of this we were able to shoot down a great many of them with anti-aircraft fire.

Of the guided missiles used during World War II, those made by the Germans were the most advanced, and the most effective. The V-1 was developed early in the war and was successfully flight tested at Peenemunde as early as the spring of 1942. By 1943, the Peenemunde Center was working on 48 different anti-aircraft missiles. Because of this dilution of effort, progress was slow. The work was later consolidated into 12 projects in an effort to get the missiles into production in time to influence the outcome of the war.

The V-1 was a robot bomb, a pulse-jet, midwing monoplane with a conventional airframe and tail construction. It used gyro stabilization and preset compass guidance. It was launched from a ramp with the help of boosters, and had to reach a speed of about 200 mph before its engine developed enough thrust to keep it airborne. V-1 missiles were launched against England in large numbers, and their 1-ton warheads did enough damage to have serious effects on morale. The V-1 missiles were slow, and after proximity fuzes were rushed to England to combat them, about 95% of them were brought down by anti-aircraft fire.

The V-2 was a large missile, with a length of 46 feet 11 inches, and a diameter of 5 feet. Its total weight at launching was over 14 tons, including a 1650 pound warhead. The V-2 was propelled by liquid-fueled rockets. It was launched vertically and preset to tilt over to a 41 to 47 degree angle a short time after launching. When it reached a speed calculated to take it to the target, its propulsion system was shut down by radio command, and it then traveled a ballistic trajectory. Its accuracy was not high, and its maximum range was only about 200 miles. The V-2 descended almost vertically on its target, at speeds of from 1900 to 3300 mph. Active countermeasures against it were impossible; no V-2 missile was ever shot down by anti-aircraft fire. If armed with a nuclear warhead, the V-2, within the limits imposed by its range, would be a formidable weapon even now.

Five other German missiles, which were in various stages of final testing when the war ended, are worth a brief mention.

Rheinbote was a surface-to-surface missile, propelled by a three-stage rocket, with booster-assisted take-off. Its overall length was 37 feet and the length of the third stage was 13 feet. The third stage carried 88 pounds of explosives, reached a speed of over 3200 mph about 25 seconds after launching, and had a range of about 135 miles.

Wasserfall was a supersonic, surface-to-air missile. It was propelled by a liquid-fueled rocket and guided by radio command. The length was 25 feet, weight 4 tons, speed 560 mph, range 30 miles, and the warhead weight 200 pounds.

Schmetterling was a smaller version of Wasserfall, intended for use against low altitude targets at ranges up to 10 miles. It carried a 55 pound warhead.

Enzian was another surface-to-air missile, designed for use against large bomber formations. Its length was about 12 feet and its wingspan about 14 feet. It carried about 1000 pounds of explosive. It was propelled by a liquid-fuel rocket and was launched with four solid-fuel booster rockets.

The X-4 was an air-to-air missile, designed for launching from fighter type aircraft. It was propelled by a liquid-fuel rocket and stabilized by four symmetrically placed fins. Its length was about 6-1/2 feet, wingspan about 2-1/2 feet, range about 1-1/2 miles, and its speed was 560 mph at an altitude of 21,000 feet. The X-4 was guided by commands from the launching aircraft, through a pair of fine wires that unrolled from two coils mounted on the tips of the missile fins. The X-4 was successfully tested before the end of the war, but it was not used in combat.

In the United States, the Army Air Corps began the development of guided glide bombs in 1941. Axon was a verticle bomb, controlled in azimuth only; it was put into production in 1943. Razon, a bomb controlled in both range and azimuth, was started in 1942 but not completed until the end of the war. A medium-angle glide bomb called the ROC, and a 12,000 pound bomb called Tarzon, both controlled in range and azimuth, were developed during the war but were not used in combat. The Tarzon project was dropped in 1946 but resumed in 1948 and Tarzon was used successfully during the Korean conflict.

In 1944, we carried out a glide-bomb mission against Cologne, Germany and a majority of the bombs reached the target area. In this same year, remote television control equipment was developed and installed in bombing aircraft. These aircraft were used to control television-sighted, explosive-laden bombers unfit for further service. These bombers saw some service over Germany in the "Weary Willie" project.

Our first jet-propelled missile was a radio-controlled flying wing; a later version was a copy of the German V-1, with a few improvements.

By the end of the war, the Navy had a number of guided missile projects in various stages of development. The Gargoyle was an air-launched, powered, radio-controlled glide bomb with a flare for visual tracking. Another Navy glide bomb, the Glomb, carried a television camera. The launching aircraft carried a monitor with which the pilot could observe the bomb's approach to the target. The Glomb was guided by radio command. The Loon was a USN version of the German V-1. The Loon was intended for shore bombardment. The Gorgon IIC was propelled by a ram-jet engine, tracked by radar, and guided by radio command. In 1944, the Navy assigned development of the Bumblebee project to the Applied Physics Laboratory of Johns Hopkins University. The project has produced the Terrier, Talos, and Tartar missiles.

MISSILE DEVELOPMENTS SINCE WORLD WAR II - As we have shown, the principal guided missile developments during the war were German. The United States lagged far behind and Japanese and British missile developments were insignificant, and as far as we know, the Russians had none at all. In 1945, the Russians captured most of the production engineers and technicians of the V-2 project, as well as several tons of missile data and perhaps a few V-2 missiles. We were luckier than the Russians. The design staff of Peenemunde, including von Braun and his principal assistants, took pains to surrender to the Americans rather than to the Russians. We also captured and shipped to the proving ground at White Sands, New Mexico, enough intact V-2 missiles and spare parts to make about 70 complete missiles.

During the first few years after the war, both American and Russian missile effort was partially devoted to assimilating the German developments. Our own experiments with the captured V-2 missiles provided valuable training for launching crews, and valuable knowledge of missile engineering. Our "V-2" program ran from March 1946 to June 1951.

The use of guided missiles as naval weapons has brought about many changes in fire control equipment. Fire control radars now have to provide for missile guidance in addition to tracking the target. Computers must solve the fire control problem and provide missile and launcher orders. Weapon Direction Systems are required to evaluate target threat and coordinate the weapon system. The latest developments in technology are required to provide fire control equipment to meet the challenge of advanced aircraft performance and advanced weapons.

Some of the Guided Missile Fire Control Systems which have been developed are:

For Terrier -- Mk 71, Mk 72, Mk 73 and Mk 76
For Tartar --- Mk 74
For Talos ---- Mk 77

To coordinate the various fire control systems, Weapon Direction Systems Mk 1, Mk 2, Mk 3, Mk 4, Mk 5, Mk 6, Mk 7, and Mk 11 have been developed.

To provide accurate designation data in range, bearing, and elevation, three-coordinate search radars including AN/SPS 48, and AN/SPS 52 have been developed and recently became the responsibility of FT's. The missiles themselves are also the responsibility of FT's.

Navy Tactical Data System (NTDS) has also been developed to coordinate fleet defense. Although FT's are not presently assigned responsibility for NTDS, they will be very closely associated with it. Many of the DS personnel were formerly FT's.

TORPEDO FIRE CONTROL AND ANTI-SUBMARINE WARFARE - Besides gun and missile systems, FT's will also be responsible for various torpedo and underwater fire control equipments.

When, during the attack on Mobile Bay on August 5, 1864, Admiral Farragut shouted "Damn the Torpedoes—Full speed ahead", he was not referring to torpedoes as we know them today. He was giving orders for his flagship and those ships following to disregard the confederate minefield guarding Mobile Bay. Until that time and for some time afterward, most devices designed to explode at or below the water line of the target ship were called "torpedoes".

As early as 1801, Robert Fulton designed and built a four man submarine, called the Nautilus, for Napoleon Bonaparte. The Nautilus was designed to deliver and explode a torpedo while submerged. The torpedo was towed at the end of a long line which passed through an eye in a spike and then to the submarine. When the submariners had driven the spike into the hull of a target, the submarine moved on drawing the torpedo up against the spike, where upon the tightening line pulled a trigger and set off the explosive. The Nautilus, in a test attack, actually blew up a ship. Napoleon lost interest in the design because of the extremely slow speed of the Nautilus.

Highly effective stationary mines were used during the Civil War, primarily by the Confederacy, in defense of ports. The most common mine was the moored "keg torpedo". The "keg torpedo" was a pitch-lined beer barrel filled with black powder and triggered by contact fuzes studded around the body. Other mines or torpedoes, including those alluded to by Admiral Farragut, variously fired by fulminate caps on contact or by shore controlled electrical impulse. These devices proved to be potent defensive weapons for use in rivers and harbors.

The first practical powered torpedo was designed in 1860 by an Englishman named Robert Whitehead. Although it contained an important feature, a hydrostatic depth regulator, its success was limited by its speed and range. This torpedo was driven by compressed air and only had a speed of 8 knots and a maximum range of 400 yards. By 1898, the speed of the Whitehead torpedo had been increased to 30 knots and the effective range to 500 yards. The increase in effective range was due to the development of a gyroscopic rudder control. This type of control, an American invention, depended on the gyroscope which is used in all types of modern fire control equipment. The Whitehead torpedo was used with varying success by the naval forces of many nations and remains the direct forerunner of the modern high speed, highly maneuverable, deadly weapon of today.

With the development of the self-propelled torpedo, a new consideration arose; how was this weapon to be delivered? Torpedos were first delivered by motor launches and launched at ranges of from 50 to 400 yards. With the advent of rapid fire guns, these small, slow speed launches became sitting ducks. The next step was the development of larger and faster torpedo boats. To combat these highly maneuverable craft, the torpedo boat destroyers were designed. The name of this type of ship was later shortened to destroyer. The first of this type displaced about 240 tons — a far cry from our modern day destroyers which displace over 4000 tons.

The torpedo was eventually installed aboard destroyers, cruisers, and even some battleships. With its high speed and devastating punch, the torpedo became a major offensive weapon. The torpedo was also carried by aircraft as a major tactical weapon capable of destroying even the largest of ships.

During World War I and World War II, torpedo boats, destroyers, and cruisers were to carry out many successful attacks against opposing warships. The tide of battle was often changed by torpedo attacks carried out by destroyers against larger ships which out-gunned them many times. Attacks by Navy torpedo planes also accounted for the destruction of many capital warships. Despite the success of these types of torpedo attacks, by far the most effective use of the torpedo was by submarines.

The science of torpedo fire control has advanced right along with the advancement of the torpedo. The only way to aim the first torpedoes was to aim the launching ship. Not until the development of the range-finding periscope and a torpedo fire control computer, did the torpedo become effective against moving targets. Subsequent to World War II, torpedo fire control has made great strides forward and with the introduction of homing and wire guided torpedoes, it may now be said of torpedo targets -- "they can run, but they can't hide".

Along with the development of the torpedo, came the necessity for anti-submarine warfare.

At the point in World War I when shipping losses by the allies to submarine attacks were most severe, two factors entered the scene and drastically changed the character of anti-submarine warfare.

The first factor was the convoy. The convoy system employed surface craft, airplanes, blimps, and dirigibles as protection for convoys of merchant ships and troop transports against submarine attacks. The early methods of attacking the submarine were ramming, bombing, or gunfire. The only means of detection was visual and therefore generally limited to daytime operations.

The second factor was the development of the depth charge and the hydrophone. The depth charge, as first used, was little more than an oil drum filled with explosives and armed with a hydrostatic fuze set to detonate at a predetermined depth. The hydrophone was a listening device that detected the motor and screw noises of the submarine. The hydrophone was directional and allowed the attacking ship to determine the bearing of the submarine. Two ships equipped with hydrophones could work together and compute both range and bearing of the submarine. One ship would then attack the submarine with either stern dropped or "K-gun" thrown depth charges. The drawbacks of this system were that the submarine could remain undetected by simply stopping its engines.

The next advance in anti-submarine warfare was the development of sonar. Sonar allowed the attacking ships to detect a submarine even though its motors were stopped. With sonar, the range, bearing, and depth of the submarine could be measured. Sonar ranges were limited to a few hundred yards, however, and thermal layers in the water could disrupt the tracking of the submarine.

To combat these deficiencies, many methods were developed to increase the range and overall coverage of the ASW (Anti-Submarine Warfare) groups. To sonar were added the capabilities of MAD (Magnetic Airborne Detection), variable depth sonar, and combined air and sea attacks.

Many weapons are presently used in ASW. These include homing torpedoes launched by a surface ship, a submarine, or a drone helicopter; depth charges dropped from aircraft or surface ships; hedgehog projectiles fired from a ship; and anti-submarine rockets (ASROC).

No matter what weapon is used, it will be directed by a fire control system. The field of fire control is continuously expanding. Each new development opens new horizons for you as an FT.. The possibilities for your growth in technical knowledge and experience is almost unlimited.

FLEET DUTIES OF AN FT

Now that you have a better understanding of fire control, let's preview what your job is going to be when you get to the fleet.

All ships include, as one of their main departments, a Weapons Department. On some ships of special type, whose primary mission is something other than ordnance, this department may be subordinated to become part of the Deck Department. On combat ships, to which an FT is most likely to be assigned, a Weapons Department is sure to be not only an independent but a major department of the ship's organization. In this case, the department is headed by a Weapons Officer who is assisted by the First Lieutenant, whose direct responsibility is deck seamanship. The department, under these two officers is responsible for the operation and maintenance of all weapons, weapons systems components, and various items of deck gear. This is the department to which the FT is regularly assigned.

Your fleet duties may be outlined briefly as follows:

1. You must be able to perform the general procedures necessary to operate and stand watch on all fire control equipment and related electronic units in your charge.

2. You must be able to maintain, test, align, calibrate, and troubleshoot all of this equipment. To perform these duties, you must be able to:

    a. Perform all periodic cleaning, lubrication, and testing required by the equipment placed in your charge.
    b. Use all tools and instruments, mechanical and electrical, necessary for the performance of your duties.
    c. Read and use mechanical drawings, blueprints, schematics, and wiring layout diagrams.
    d. Locate troubles and make necessary repairs.

3. You must be able to go through the procedures necessary to requisition and stow all parts and supplies required in your work. You must also be able to prepare work requests as needed.

4. You must be able to maintain fire control records according to the established format.

5. You must be able to boresight guns and align weapon systems.

6. You may be called upon to inspect and adjust optical instruments associated with fire control equipment.

7. You must be able, under supervision, to install fire control equipment and accessories and to make certain field changes of a limited nature.

Do not let this list of duties throw you. You will not have them piled on your shoulders all at once. When you get aboard ship, you will find that there are already a few FT's aboard who have been doing this job for some time. They will help you get started on the right foot.

Now that you have made a quick survey of your fleet duties, let's see how they fit into the larger picture of fire control duty afloat. You probably have many questions concerning the type of ship on which you will be stationed, the number of hours a day you will be on duty, whether you will be working by yourself or as a member of a crew, what your combat duties will be, what your maintenance duties will be, etc.

The information which follows will answer most of these questions for you.

WATCHES - A ship at sea does not shut down for the night. Someone is always on watch aboard your ship. One or more electrician mates are on duty day and night. The various lookout stations are always manned. In short, every vital service on board a ship must have someone on watch at all times. In order to maintain this 24-hour vigilance, the watch system was established long ago on board all ships. The various watches are as follows:

0000-0400	Mid-watch
0400-0800	Morning watch
0800-1200	Forenoon watch
1200-1600	Afternoon watch
1600-1800	First Dog watch
1800-2000	Second Dog watch
2000-2400	Evening watch

The two "Dog" watches are shortened, or dogged, to give those on duty a chance to eat their evening meal and share in the recreation period. Your place in the ship's organization and your stations for the various shipboard drills will be posted on your divisional bulletin board. In addition, you may be given a "billet slip", which will give you the details of your assignments.

When a ship is at sea the watches are arranged as described above and are called cruising watches. Under war conditions or on maneuvers there are four conditions of readiness for battle or simulated battle conditions. These are:

Condition IV - There is no probability of action and the regular watch conditions prevail.

Condition III - There is possibility of attack at any time. Watch conditions are four hours on and eight hours off.

Condition II - There is possibility of attack at any time. Watch conditions are four hours on and four hours off.

Condition I - This is the same condition as general quarters. Everyone is at his battle station and attack is imminent. All equipment is tested and ready for action.

General quarters (GQ) is sounded whenever there is danger of immediate attack, whenever a lookout spots a periscope, when radar detects an unidentified plane, or when sonar detects a submarine. Condition I also exists when the ship has entered waters under surveillance by the enemy or under any other conditions where there is known danger of attack. The announcement of GQ will differ according to the ship; but, no matter what type of ship you are on, it will be unmistakable. GQ may be announced by the continuous sounding of a bell, a siren, or a horn; or by the words "general quarters" or a bugle call over the loud speaker system. When you hear GQ, you stop whatever you are doing and go to your assigned battle station.

MAINTENANCE DUTIES - If you have ever taken care of an automobile, a bicycle, or a plain old-fashioned adding machine without any electronic trimmings, you must know that it is much easier to keep a machine properly serviced than to repair a breakdown. Take the case of an automobile. It is easier to keep the air in a tire at the proper pressure than to fix a blowout on a busy highway. It is easier to keep the crankcase oil at the correct level than to have to replace the bearings. It may take only two minutes a week to keep the radiator full, but it may take ten hours and many dollars to repair the damage caused by overheating. For the same reasons, you have to inspect the brakes, clean and adjust the spark plugs, and adjust the distributor points. By taking time to do this maintenance work, you save yourself the much more extensive work and expense that would be necessary in the event of a breakdown. In addition, by driving a safe car on a fast highway, you may be saving the lives of other people or your own life.

It is the same story with all types of electrical and electronic equipment. If you average out all the maintenance work that should be done, you will find that it requires only a relatively small part of each day. By doing this very modest amount of work, you may avoid a breakdown that would occupy you for many hours or perhaps necessitate calling on a man of some other rating to put your equipment in shape again. Finally, a little maintenance work every day is a low price to pay for insurance against a breakdown at a crucial moment in combat.

A complete weapons system of a ship contains many complex units and any one of these units may contain a vast number of electrical and mechanical components. Although many of the parts may appear to be quite delicate in construction, you will learn that they have been designed for a very long life expectancy. Under ideal conditions, this equipment could operate for long periods with no maintenance other than the replacement of mechanical parts which are subject to wear. You must be prepared, however, to find that conditions aboard ship are far from ideal for electronic equipment.

Electrical and electronic equipment aboard ship is exposed to mechanical shocks, vibration, dampness, salt action, wide variations in temperature, and possible mishandling by inexperienced personnel. These conditions cause breakage, loosening of connections, excessive wear, corrosion, loss of adjustment, and breakdown of insulation. It is the purpose of maintenance to keep this kind of wear and tear to a minimum and, where it does occur, to detect and correct it before serious damage develops.

You can combat the conditions described above by lubrication, cleaning, inspection, and periodic performance testing. You probably already understand the principles of lubricating surfaces which move against each other. The details as to what and when to lubricate and the correct oils and greases to be used are explained in equipment publications.

Cleaning is of particular importance with reference to the effects of dampness and salt action. Dirt absorbs moisture, and moisture aboard ship is likely to contain particles of salt. Salt water has a corrosive action on metal surfaces. Moral: It is important to keep your equipment both dry and clean.

Finally, you will find that conditions affecting maintenance vary in different locations on the earth. This means you will have to adjust your schedules for lubrication and cleaning.

Now that you have been introduced to the two main duties of an FT, let's consider some of the secondary aspects of your job. These secondary requirements make it possible for you to discharge your major responsibilities more effectively.

It should be obvious that you can not make repairs, however minor, or do any of the necessary servicing of your equipment unless you have the right supplies and spare parts on hand. It should also be evident, that in order to have the right things on hand at the right time, you must know what to order, when and how to order and also how to store the various supplies so there will be no loss, breakage, or other deterioration. To some people, the standardization of procedures for things of this nature is always irksome. It seems to them a lot of unnecessary paper work to have to fill out certain forms in the required manner, with a specified number of copies, and to obtain several different signatures of approval. To anyone who gives it a little thought, however, it should be obvious that the routines are necessary and desirable. In no other way could the large-scale distribution of parts and supplies be directed effectively.

In the same way, certain standard procedures must be carried out in order to get work done by a member of some other rating. These procedures have been devised and systematized in order to accomplish various tasks efficiently. It might seem simpler for an FT merely to shout to an EM of his acquaintance, "Hi Mac, drop around when you're not busy and take a look at this motor; it isn't working right". You will find, however, that it gets you further to notify your supervisor in the approved manner when you have a repair problem beyond your facilities.

When changes have to be made to existing electronic units associated with fire control equipment, or when new equipment is to be installed on board a ship, the work is usually done at a naval base or by a special team of technicians sent on board for that particular purpose. Sometimes, however, the work is simple enough to be done by the ship's technician force. At other times, although the work may be quite complicated, it is of such importance that there must be no delay and the job is also assigned to the ship's force.

To alter equipment or to make new installations, you will have to know how to read and use mechanical drawings, blueprints, schematics, and wiring layout diagrams and you will have to know how to use various tools and all types of test equipment. This type of work will be done under the direction and supervision of a petty officer; but you will be expected to perform your share of the work.

If all problems of maintenance could be solved by proficient lubrication and cleaning, you would only have to work out the best possible schedule for giving your equipment this care and then follow the schedule; but this will not do the whole job, you must also watch for troubles which have not or cannot be prevented by cleaning and lubrication.

Periodic inspection and performance testing will help locate troubles that are in the early stages of development and have not caused a breakdown. The former should include examination of tube sockets, electrical connections, switch contacts, cable runs, and mechanical components. Any sign of wear, cracking of insulation, corrosion, or breakage should be corrected immediately by repair or replacement of the affected parts.

Performance testing locates developing troubles which cannot be found by visual or resistance checks. Definite standards of transmitter power, receiver sensitivity, and frequency range must be met. By putting your equipment through standard tests, you can tell whether or not its operation is satisfactory in all respects. A systematic schedule for such tests, inspections, and checks as have been described, calls for certain routines to be followed daily, weekly, monthly, quarterly, or annually. When you find that something is not performing up to standard, you will go through regular troubleshooting procedures to locate the cause. The condition to be corrected may be a weak tube, a tuned circuit out of adjustment, or some other electrical or mechanical malfunction. You will be qualified to find and correct such conditions when you have studied the vehicular equipment for your rating.

PATHS OF ADVANCEMENT

You have become one of a select group of men chosen to become Fire Control Technicians. How far up the ladder of success you go depends entirely upon how much you are willing to apply yourself. There are many paths you may take on your climb to the top.

Training a man to operate and maintain complex electronic equipment is time consuming and expensive. This is the reason why the Navy requires you to have a specific amount of obligated service before they send you to various schools. It is not economically sound practice for the Navy to provide expensive, specialized training for a man and not be able to benefit from his experience.

The FT rating is presently divided into two groups; these are FTG and FTM. FTG's are associated primarily with conventional gun fire control systems and FTM's specialize in missile fire control systems. Several of the GFCS, including Mk 56 and Mk 68, and all of the MFCS require training of such duration that the Navy can only offer this training to a man who is obligated for six years of active duty. Regardless of the path you choose, your career in the Navy can be a valuable, rewarding experience.

If you decide to become an FTG and not obligate for six years, your career may look something like this. After completing 18 weeks of FT "A" School, most of you will be ordered to a ship equipped with conventional weapons. Conventional weapons provide a necessary defense against certain types of air and surface targets and are also the most used means of conducting shore bombardment, as evidenced by the Korean conflict. It has become necessary to install these weapons on the various missile ships to augment the missile battery, thus providing these ships with efficient and highly effective short range air and surface protection and better shore bombardment capabilities. All of these modern conventional systems offer a challenge to you as an FT. Numerous, specialized "C" school maintenance courses of 2 to 8 weeks in duration are now available to FTG's.

If you decide to become an FTG specializing in the Mk 56 or Mk 68, or an FTM specializing in one of the missile system components, your career may look something like this. You will be required to obligate yourself to the Navy for six (6) years. This six years includes the time that you have already served on your current enlistment. Here is how it shapes up. Chances are you are in for a four year enlistment and for a two year extension you will get the following: Instead of only the 18 week FT "A" school you will get an additional fourteen (14) weeks of specialized training and you will be assigned to a minimum of twenty (20) weeks in a "C" course. In addition to the extensive training you receive, you may also be eligible for automatic advancement to third class if you qualify under the existing instruction covering automatic advancement. Upon completion of the "C" course you will be sent to sea for a tour of approximately two years, enabling you to gain valuable practical experience on the equipment for which you have been trained. Upon completion of this training period, and if you have followed the normal advancement pattern (see illustration on facing page), you will be an FT2 (E5). At this time you may be sent to another "C" course, of 20 or more weeks duration, to receive training on another equipment in the field with which you are associated and then back to sea for additional training. After this period at sea, you should have advanced to FT1 (E6). This then would complete your six years of obligated service and it is the Navy's hope, that after having received all

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	† E4 to E5	† E5 to E6	‡ E6 to E7	‡ E7 to E8	‡ E8 to E9
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E-2.	6 mos. as E-3.	12 mos. as E-4.	24 mos. as E-5.	36 mos. as E-6.	48 mos. as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.	▨	Class A for PR3, DT3, PT3. ǂ AME 3	▨	▨	Class B for AGCA, MUCA, MNCA.		
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST	▨		Specified ratings must complete applicable performance tests before taking examinations.				▨	▨
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.				Service-wide, selection board, and physical.	
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)	▨	Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		U.S. Naval Examining Center			Bureau of Naval Personnel		
	TARS attached to the air program are advanced to fill vacancies and must be approved by CNARESTRA.							

*ALL ADVANCEMENTS REQUIRE COMMANDING OFFICER'S RECOMMENDATION.
† 1 YEAR OBLIGATED SERVICE REQUIRED.
‡ 2 YEARS OBLIGATED SERVICE REQUIRED.
ǂ EFFECTIVE 1 JAN. 1963.

1. ACTIVE DUTY ADVANCEMENT REQUIREMENTS

of this specialized training and advancement in rating, you will have decided to continue your naval career.

Another enlisted program you will be wise to investigate is STAR (Selective Training And Retention). E3's and E4's are only eligible for this program after completion of one year service and prior to completion of three years. E5's are eligible prior to completion of forty two (42) months. To enter this program you must re-enlist for six (6) years. You are guaranteed assignment to "A", "B", or "C" school as appropriate, and automatic advancement to E4 or E5 under certain conditions. You are eligible for re-enlistment bonus. If an E4 were to ship STAR, he would become eligible for specialty pay (P1 - $50, P2 - $75, or P3 - $100) merely by being "career designated".

The Navy will also make available to you various correspondence courses to aid your development. These enlisted correspondence courses are available at no cost to you. In addition, the United States Armed Forces Institute (USAFI) has available at all levels, courses on almost any subject. For these courses there is an initial fee of $5.00.

In addition to the preceding programs, you may also be eligible for various programs which lead to a commission as an officer.

Requirements for eligibility may change with time so you should consult your training office for the latest information. The opportunity and challenge are there: Will you accept them?

SCOPE AND OBJECTIVES OF FT SCHOOL

The course of instruction is divided into two phases. Phase I which is the basic FT "A" School is eighteen (18) weeks in duration. All of you who maintain the required level of proficiency will complete this portion of the course. Those of you who choose to extend your enlistment for a total of six (6) years, and who meet established requirements, will receive an additional fourteen (14) weeks of training. This portion of the course, Phase II, will be know as the "Weapons Preparatory Course". Upon completion of Phase II, you will be assigned to a specialized class "C" course on some particular equipment. You will receive more information regarding this program at a later date. The following is a brief synopsis of the course.

Phase I

Weeks 1-2: Introduction to Fire Control- The first two weeks of your training is to acquaint you with some of the duties of an FT, the history of fire control, and some of the various equipments with which you may come in contact. You will learn some of the special language of an FT. Physical phenomena which are involved in the solution of the fire control problem as well as the symbols used to designate the various quantities will be studied. You will also learn to solve the problem mathematically. It is necessary for all FT's to understand the mathematical solution in order to efficiently operate and maintain the complex equipment which is used to solve the fire control problem in actual practice.

Weeks 3-7: Basic Electricity- It is impossible to effectively study fire control equipment without first understanding the basic principles which govern the operation of the various circuits and devices used in fire control equipment. During these five (5) weeks you will learn about the composition of matter, the electron theory, and magnetism. You will learn what electricity is and how it is generated. You will learn the difference between direct current (DC) and alternating current (AC). You will learn what resistors, capacitors, and inductors are and how they function. You will also learn how to solve basic circuit problems.

Weeks 8-14: Basic Electronics- During these seven (7) weeks you will learn the basic operating principles of vacuum tubes and semi-conductor devices including transistors. You will apply the knowledge gained in basic electricity to combine resistors, capacitors, inductors, tubes, and transistors to form the various types of electronic circuits. You will utilize various test equipment to study these circuits which include power supplies, amplifiers, and oscillators.

Weeks 15-17: Basics of Magnetic Amplifiers, Rotating Machinery, Synchros, and Servos- During these three (3) weeks you will learn how magnetic effects are utilized to provide amplification, generate electricity, rotate machinery, provide information and control, and many other useful functions. Magnetic amplifiers are used in some computers, control circuits, and various other fire control equipment. Rotating machinery (motors and generators) have many applications. Synchros are used to transmit director position, gun orders, and other information. Servo systems use magnetic amplifiers, synchros, and other devices to provide control for such things as director positioning.

Week 18: Gyroscope Fundamentals - Navy Maintenance Management System - and Naval Supply System - Practically all fire control equipment makes use of gyroscopes or some other device based on gyroscopic action. During this week you will learn the basic principles of gyroscopic action and see how gyros function in several fire control applications. Also during this week, you will be introduced to a maintenance scheduling and documenting system which has been implemented throughout the Navy to insure efficient preventive maintenance. You will also be introduced to the supply system since you will have to cooperate with supply personnel in the ordering of various parts and equipment.

Phase II

Weeks 19-22: Fire Control Electronics - During these four (4) weeks of advanced training, you will learn more about various electronic circuits. You will study amplifiers, oscillators, etc. and the examples used will be special designs of basic circuits for a particular application.

Week 23: Test Equipment - During this week you will study and work with some of the test equipment you will have in the fleet.

Weeks 24-28: Computers - During these five (5) weeks you will study analog computers and learn how they are used to solve the fire control problem. You will also be introduced to some of the circuits and techniques used in digital computers. The section on digital computers will include an introduction to binary arithmetic and Boolean algebra.

Weeks 29-31: Radar Principles - In these three (3) weeks you will study transmission lines, ferrite devices, microwave devices, and other specialized circuits in a working radar.

Week 32: Fire Control Radar System - During this week a Mk 25 radar will be used as a training vehicle so that all of your previous training can be tied together in a working piece of equipment. You will use OP's and test equipment to study the functioning of the various circuits in operation.

REVIEW AND SUMMARY

You have learned that your duties in the fleet will be both military and professional. From the history of fire control you should have learned that the field of fire control is constantly changing and new technology applied to fire control equipment. As an FT you have both the opportunity and challenge to keep up with the latest advances. The Navy will provide you with numerous correspondence courses to aid in your quest for knowledge. How far you go is up to you.

TOPIC 2: SECURITY

YOU ARE NOW GOING TO LEARN:

1. What security is.
2. What OPNAVINST 5510.1B is.
3. Definition of terms applying to security.
4. Classification categories.
5. How to care for classified material.
6. About violations, disciplinary action, control of dissemination, and control of photography.
7. About criteria for personal security clearances.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. What security is.
2. OPNAVINST 5510.1B.
3. Definitions of terms applying to Security:
    a. Access.
    b. Clearance.
    c. Compromise.
    d. Need to know.
4. Classification categories:
    a. Top Secret.
    b. Secret.
    c. Confidential.
5. Care of classified material.
6. Violations, control of dissemination, and control of photography.
7. Clearance criteria.
8. Review and summary.

INFORMATION AND DISCUSSION:

WHAT SECURITY IS

Security is defined in "Webster's Dictionary" as: 1. The quality or condition of being secure; specifically: a. Freedom from exposure to danger; protection; safety or a place of safety. b. Feeling of or assurance or safety or certainity; freedom from anxiety or doubt. 2. That which secures; a means of protection, defense, etc.

As used in this topic, security is a means of protection, defense, etc. As an FT, much of your work will deal with classified material. It is your duty as well as moral obligation to protect all classified material. Everyone should be security conscious; an FT should be especially so because of the nature of his work. Furthermore, to be effective, security must not only be a means; it must also be an attitude.

Security should be a very personal thing to you. Honest, trustworthy, and conscientious are three words associated with obtaining a security clearance. If you have a clearance, it means you have shown yourself to be honest, trustworthy, and conscientious. These personal characteristics are to be admired in others and treasured in yourself. Be continually on guard so there will never be any question as to your honesty, trustworthiness, or conscientiousness. Need to know is another term used when talking about security. Your job may be very interesting and you may be anxious to discuss it with your shipmates, friends or family; however, you must remember that some of the information may be classified and should never be discussed in the presence of anyone who does not have a need to know, even though they have a security clearance. Valuable information is often given away by indiscrete conversation. In addition to talking about classified material, you must be conscientious in handling classified written material or equipment. At all times you must protect the security of your country as well as the security of your reputation. Security is a personal attitude. Develop it well!

OPNAVINST 5510.1B

This is the Department of the Navy's "Security Manual for Classified Information". It provides all naval activities and personnel with detailed regulations and guidance for classifying, marking, and handling classified information and for access thereto and disclosures thereof. The excerpts which follow are to introduce you to this instruction and provide you with some of the fundamental concepts of security.

Chapter 1 - Introduction (Excerpts)

0101. Responsibility

1. The Chief of Naval Operations is responsible to the Secretary of the Navy for all policies relating to the maintenance of the security of all classified information within the Naval Establishment. Owing to the close relationship of counterintelligence and the preservation of security, the Director of Naval Intelligence has been designated as the officer primarily responsible to the Chief of Naval Operations for the protection of classified information. Therefore, the office of Naval Intelligence formulates and promulgates Navy policies which relate to the security of all classified information.

2. Commanding Officers are directly responsible for safeguarding all classified information within their commands and are responsible for instructing their personnel in security practices and procedures.

0102. Objective

1. The objective of the orders and instructions which appear herein is to establish a coordinated policy for the maintenance of the security of all information classified in the interests of national defense.

2. Information which requires administrative protection for reasons other than in the interests of national defense is not classified information as defined in this instruction and the protective measures established herein do not apply. Originators of such information are responsible for insuring its identification and protection in accordance with the existing regulations. Under no circumstances shall the designation Top Secret, Secret, or Confidential (including Confidential Modified Handling Authorized) be assigned to such information.

0103. Application

The security of the United States in general, and of naval operations in particular, depends in part upon the success attained in the safeguarding of classified information. It is of paramount importance that all who engage in administering security preserve a balanced and common sense outlook toward the subject. The ideal to be sought is the indoctrination of all personnel to the point that they automatically exercise proper discretion in the discharge of their duties and do not think of security of information as something separate and apart from other things. In this way, security of classified information becomes a natural element of every task and not an additionally imposed burden. The attainment of the desired objective requires sound direction from above and full alertness and cooperativeness on the part of all subordinates.

0105. Limitations of Security

Security is a means--not an end. Rules which govern security of classified information are comparable to gunnery safety orders. They do not guarantee protection, and they do not attempt to meet every conceivable situation. The law of diminishing returns limits the control measures that can be employed profitably, but it is possible to obtain a satisfactory degree of security with a minimum of sacrifice in operating efficiency.

0106. Security Principle

The Department of Defense is employing a security formula which is simple in principle. It is based on the premise of circulation control; i.e., the control of the dissemination of classified information. Therefore, knowledge or possession of classified defense information shall be permitted only to persons whose official duties require such access in the interest of promoting national defense and only if they have been determined to be trustworthy.

0107. General Interpretation

In the interpretation of the provisions of this publication, each command and individual shall be guided by the basic principle of security. The regulations contained herein are not intended to restrict the mature judgement of individuals in the proper application of initiative. It is directed that commands issue additional security instructions as necessary to meet local situations.

DEFINITION OF TERMS APPLYING TO SECURITY

As an aid to understanding, the following definitions are supplied.

Chapter 2 - Definitions (Excerpts)

0201. Access

Access is the ability and opportunity to obtain knowledge or possession of classified information. An individual does not have access to classified information merely by being in a place where such information is kept, provided the security measures which are in effect prevent him from gaining knowledge or possession of such classified information.

0203. Categories of Classified Information

There are three categories of classified information which, in descending order of importance, shall carry one of the following designations: Top Secret, Secret, or Confidential (including Confidential-Modified Handling Authorized).

0204. Classification Guide

An instruction indicating the classification that may be assigned to subjects within a specific area of defense activity.

0205. Classified Information

Classified information is official information which requires protection in the interests of National defense and which is classified for such purpose by responsible classifying authority.

0206. Classified Material

Classified material is any matter, document, product, or substance on or in which classified information is recorded or embodied.

0209. Clearance

A clearance is an administrative determination by competent authority that an individual is eligible, from a security standpoint, for access to classified information of a specified category.

0213. Compromise

A compromise is a loss of security which results from an unauthorized person obtaining knowledge of classified information. As used in this instruction, the term, unauthorized person, means any person not authorized to have access to classified information.

0225. Information

Information is knowledge which can be communicated by any means.

0230. Need to Know

Need to know is the term given to the requirement that the dissemination of classified information be limited strictly to those persons whose official military or other governmental duties require knowledge or possession thereof. Responsibility for determining whether a person's duties require that he possess or have access to classified information and whether he is authorized to receive it rests upon each individual who has possession, knowledge, or command control of the information involved and not upon the prospective recipient. This principle is applicable whether the prospective recipient is an individual, a command, a defense contractor, another federal agency, or a foreign government. A need to know is recognized as established when (1) the disclosure is necessary in the interests of national defense (2) there clearly appears from the position, status, duties, and responsibilities of the applicant a legitimate requirement that he must have access to the classified information in order to carry out his assigned duties and responsibilities; (3) there is no other equal of ready source of the same classified information available to him; and (4) the applicant is or can be appropriately cleared for access to the degree of classified information involved and is capable both physically and mentally of providing the degree of protection which that information requires.

CLASSIFICATION CATEGORIES

You will note from the descriptions which follow, that the key to the classification used is the degree of possible consequence that may result due to unauthorized disclosure of the material.

Chapter 3 - Classification Categories (Excerpts)

0301. General

Official information which requires protection in the interests of national defense shall be limited to three categories of classification which, in descending order of importance, shall carry one of the following designations: Top Secret, Secret, or Confidential (including Confidential-Modified Handling Authorized). No other designation shall be used to classify defense information, as requiring protection in the interests of national defense, except as expressly provided by statute. Official information not affecting the national defense, which pursuant to statutory or constitutional authority may be deemed to require protection in the public interest for other reasons, shall be handled in accordance with SECNAV Instruction 5570.2A.

0302. Definition of Top Secret

The use of the classification Top Secret shall be limited to defense information which requires the highest degree of protection. The Top Secret classification shall be applied only to that information or material the defense aspect of which is paramount, and the unauthorized disclosure of which could result in exceptionally grave damage to the Nation.

0303. Definition of Secret

The use of the classification Secret shall be limited to defense information or material the unauthorized disclosure of which could result in serious damage to the Nation.

0304. Definition of Confidential (Confidential-Modified Handling Authorized)

The use of the classification Confidential shall be limited to defense information or material the unauthorized disclosure of which could be prejudicial to the defense interests of the Nation.

CARE OF CLASSIFIED MATERIAL

Chapter 6 - Custody (Excerpts)

0613. Individual Responsibility

1. All personnel in the Naval establishment are individually responsible for assuring that knowledge of classified information which they prepare or handle is made available only to persons who have appropriate security clearances and who have clearly established a legitimate need to know.

2. Personnel of the Naval establishment shall not remove classified material from the physical confines of the command without the knowledge and approval of the commanding officer or his authorized representative. When classified material is so removed, as when it is taken to

conferences or other offices in a local area, a complete list (receipt) shall be prepared, signed by the individual removing the material, and appropriately filed until the material is returned. This procedure is apart from that applicable to personnel in a travel status (see 0705), to regularly authorized couriers (see 0710), or to personnel transmitting or routing classified material within commands or between specifically designated activities (see 0704).

0614. Care During Working Hours

1. Each individual in the Naval establishment shall take every precaution to prevent deliberate or casual access to classified information by unauthorized persons. Among the precautions to be followed are:

a. When classified documents are removed from stowage for working purposes, they shall be kept face down or covered up when not in use.
b. Visitors not authorized access to the particular classified information within the working space shall be received or interviewed in specially arranged reception rooms or areas.
c. Classified information shall not be discussed over the telephone. Telephone scrambling devices do not assure security.
d. Preliminary drafts, carbon sheets, plates, stenciles, stenographic notes, worksheets, and all similar items containing classified information shall be either (1) destroyed by the person responsible for their production immediately after they have served their purposes, or (2) shall be given the classification and safeguarded in the same manner as the classified information produced from them.
e. Classified material, upon receipt, shall be opened by the addressee or by persons specifically authorized by him to open material of the grade involved.

2. If, for any reason, a room must be vacated during working hours, the classified material therein must be stowed in the manner prescribed in 0615.

0615. Care After Working Hours

1. Commanding officers shall institute a system of security checks at the close of each working day to insure that the classified material held by the command is properly protected. They shall require the custodians of the classified material to make an inspection which shall insure, as a minimum, that:

a. All classified material is stowed in the manner prescribed in Chapter 6, Section 1.
b. All classified material which must be passed from watch to watch is properly accounted for.
c. Burn bags are properly stowed or destroyed.
d. The contents of wastebaskets which contain classified material have been properly stowed or destroyed.
e. Classified shorthand notes, carbon paper, rough drafts, and similar papers have been properly stowed or destroyed. As a matter of routine during the day, such items shall be placed in burn bags immediately after they have served their purpose.

2. Commanding officers shall assure that all personnel concerned are indoctrinated in the requirement for rotating the dial of all combination locks at least three complete turns in the same direction when securing safes, files, or cabinets so equipped. In most locks, if the dials are given only a quick twist, it is generally possible to open the lock merely by turning the dial back in the opposite direction. Additionally responsible personnel shall be required to assure themselves that all drawers of safes and file cabinets are held firmly in the locked position when such equipment has been secured.

3. Commanding officers shall prescribed procedures whereby appropriate identification of the individual responsible for the contents of each container of classified material shall be readily available.

0617. Care During Emergencies

In the event of a fire alarm or other emergency, classified material shall be stowed in the same manner as at the end of a working day. Each person who has classified material in his possession at the time of a fire alarm or other emergency shall assure that such material is properly safeguarded.

VIOLATIONS, CONTROL OF DISSEMINATION, AND CONTROL OF PHOTOGRAPHY

Chapter 8 - Security Violations and Compromises (Excerpts)

0802. Sabotage or Espionage

Individuals becoming aware of possible acts of sabotage, espionage, or other subversive activities shall report immediately all available information to the most readily available command who in turn shall notify immediately the Director of Naval Intelligence or the cognizant Naval District Intelligence Officer, as appropriate.

0804. Security Violations

1. Violations of regulations pertaining to the safeguarding of classified information, but not resulting in its loss, compromise, or unauthorized disclosure shall be acted upon by the commanding officers of the persons involved without reference to other authority. The fact that a breach of security regulations has occurred may, in the discretion of the commanding officer, be considered as sufficient justification for some form of disciplinary action, whether or not there has been a loss or possible subjection to compromise. The circumstances of the case, including the degree of culpability, should always be considered in determining when disciplinary action is appropriate.

2. Persons in command status shall establish such measures for the security inspection of safe-stowage containers and of areas where classified material is maintained as are necessary to assure compliance with security regulations.

3. Persons in command status who receive classified material which shows improper handling by the activity from which received will promptly advise the commanding officer of that activity.

0805. Disciplinary Action

Individuals found responsible for the loss, unauthorized disclosure or possible subjection to compromise of classified information, and individuals who violate security regulations, shall be promptly and adequately disciplined regardless of rank or position. Even where it is impossible to identify the specific individual source of an unauthorized disclosure of classified information, disciplinary action is not necessarily precluded. Where the source can be traced to a specific command or office, the commander or official in charge shall be held responsible for any derelictions of ineffectiveness in the discharge of his responsibilities in such manner as may be warranted in the circumstances. Disciplinary action may include, in the case of military personnel, trial by court martial or, in the case of civilians, processing under the Standard Schedule of Disciplinary Offenses and Penalties for Civilian Employees in the Naval Establishment included in NCPI 45, prosecution under title 18, U. S. C. as amended, or other Federal statutes as appropriate. Offenses by civilian employees of the Navy shall be reviewed for applicability of the Act of 26 August 1950 (5 U. S. C. 22-1 et seq.) and Executive Order 10450 as amended pertaining to security risks.

Chapter 9 - Control of Dissemination (Excerpts)

0909. Personal Censorship

1. Indiscreet conversation and personal letters constitute great menaces to security. This applies especially to persons discussing office affairs with their families or friends. It also applies to careless talk on duty in the presence of persons not authorized to have the information. Loose talk in public places and over the telephone is also most dangerous. Information imparted to unauthorized persons within or outside the Naval

establishment may be repeated innocently and in ignorance of its importance until it becomes a matter of common knowledge. Foreign intelligence agents are scientifically trained to collect and to collate numerous bits of seemingly harmless information from conversation and rumors which circulate in the vicinity of naval activities. Therefore, automatic personal censorship of official and unofficial conversation and letters shall be a fundamental duty of all personnel of the Navy establishment. The habit must be cultivated until it becomes routine.

2. When classified information is discussed orally, the audience shall be informed of its classification.

3. The debriefing of personnel leaving Department of Defense employment, or leaving the employment of Department of Defense contractors having classified contracts, must incorporate positive instructions against disclosures of classified information. Similar positive procedures shall be applied in the case of military personnel retiring or separating from the service.

0910. Telephone Conversations

Classified information shall not be disclosed over telephones because of the insecurity due to executive cut-in, phantom voice interception, and wire tapping.

0913. Prisoners of War

1. The United States is a party to the Geneva Convention Relative to the Treatment of Prisoners of War (12 August 1949), and the provisions of this Convention are binding on personnel of the naval service.

2. Pursuant to the provisions of article 17 of the above Convention, each prisoner of war, when questioned on the subject, is bound to give only his full name, grade or rate, service number, and date of birth. All members of the naval service shall comply with these provisions in case of capture.

3. Prisoners can expect to be questioned upon capture. During such interrogations they shall not give any information other than their names, grades or rates, service numbers, and dates of birth. Threats, inducements, promises, and subterfuges might be used by the enemy to extract information. Seemingly harmless subjects, such as baseball and golf, should not be discussed while undergoing interrogation, as a trained interrogator can often extract the information he desires through such a discussion. There is no such thing as a harmless subject of discussion while a prisoner is held in an enemy interrogation center. (See General Order No. 4, Code of Conduct for Members of the Armed Forces of the United States, 18 March 1957.) Prisoners shall endeavor to communicate promptly their names, grades or rates, service numbers, dates of birth, and prison addresses to the International Red Cross Committee, Geneva, Switzerland. No other information shall be given for use by the Red Cross.

Chapter 11 - Control of Photography
(Excerpts)

1101. Responsibility

1. Persons in a command status shall be responsible for controlling the photographing of all material within their jurisdiction. This applies to official and unofficial photography, regardless of whether the photographers are attached to the Naval establishment or are private citizens. Additional directives shall be promulgated by commands as necessary to control photography within the respective command.

2. When competent authority higher than the commanding officer authorizes the taking of official or unofficial photographs, such authority in no way relieves the local authority from responsibility for supervision, censorship, and release of resulting photographs, unless so specified.

3. The taking of unofficial photographs within naval jurisdiction is forbidden, unless specifically authorized.

4. Visitors shall not be allowed to take photographic equipment into a naval shore establishment or on board a naval ship or aircraft unless specifically authorized by the commanding officer.

1102. Photographs of Naval Personnel and Defense Contractors

1. A commanding officer, or higher authority, may authorize naval personnel or defense contractors to act as official photographers for his command. Developing and printing incident thereto shall be accomplished under naval jurisdiction.

2. Naval personnel shall be allowed to bring cameras on board ships and aircraft or into shore installations only as authorized by commanding officers and subject to such restrictions for the protection of classified information as they may impose. They shall not be used on board ship for official or unofficial purposes without the authorization of the commanding officer. In case the commanding officer authorizes the use of cameras on board for unofficial purposes, he shall insure that resulting photographs do not reveal classified information.

CLEARANCE CRITERIA

Due to the fact that a great deal of your work involves classified material, your future in fire control is somewhat determined by your capability to be cleared for access to various levels of classified material. All of you as students in FT "A" School have been cleared for Confidential, however, some of the information for many of the fire control systems carries a higher classification; it is important therefore, that you take every precaution to safeguard your capability of receiving and maintaining a clearance.

Chapter 15 - Personnel Security Investigations and Clearances for Access to Classified Information (Excerpts)

1505. Clearance Criteria

1. Personnel authorized access to classified information must be:

a. Of unquestionable loyalty, integrity, and trustworthiness.
b. Of excellent character and of such habits and associations as to cast out doubt upon their discretion or good judgement in handling of classified information.

2. Access to classified information shall be granted only when it has been determined that such access is clearly consistent with the interests of national security.

3. The activities and associations listed below may be the basis for denial or termination of clearance, but they are varying degrees of seriousness. Therefore, the ultimate determination of whether clearance should be granted, denied, or terminated must be an overall commonsense one, based on all available information concerning the following:

a. Commission of any act of sabotage, espionage, treason or sedition, or attempts, thereat or preparation thereof, or conspiring with or abiding or abeting another to commit or attempt to commit any act of sabotage, espionage, treason or sedition.
b. Establishing or continuing a sympathetic association with a saboteur, spy, traitor, seditionist, anarchist, or revolutionist, or with an espionage or other secret agent or representative of a foreign nation whose interest are inimical

to the interests of the United States, or with any person who advocates the use of force or violence to overthrow the government of the United States or the alteration of the form of government of the United States by unconstitutional means.

c. Advocacy of use of force or violence to overthrow the government of the United States, or of the alteration of the form of government of the United States by unconstitutional means.

d. Membership in, or affiliation or sympathetic association with, any foreign or domestic organization, association, movement, group, or combination of persons which is totalitarian, fascist, communist, or subversive, or which has adopted, or shows, a policy of advocation or approving the commission of acts of force or violence to deny other persons their rights, under the Constitution of the United States, or which seeks to alter the form of government of the United States by unconstitutional means. (An organization, movement, or group, officially designated by the Attorney General of the United States to be totalitarian, fascist, communist, or subversive, to advocate or approve forcible or violent denial of Constitutional rights, or to seek alteration of the form of government of the United States by unconstitutional means, shall be presumed to be of a character thus designated until the contrary be established.)

e. Performing or attempting to perform his duties, or otherwise acting, so as to serve the interests of another government in preference to the interests of the United States.

f. Failure or refusal to sign loyalty certificate, or pleading protection of the Fifth Amendment or of Article 31, Uniform Code of Military Justice, in refusing to completely answer questions contained in required security forms or personal history statements; pleading protection of the Fifth Amendment or Article 31, Uniform Code of Military Justice, or otherwise failing or refusing to answer any pertinent question propounded in the course of an official investigation, interrogation, or examination, conducted for the purpose of ascertaining the existence or extent, or both, of conduct of the nature described in (a) through (e) above and (g) through (m) below.

g. Participation in the activities of an organization established as a "front" for an organization referred to in (d) above, when his personal views were sympathetic to the subversive purposes of such organization.

h. Participation in the activities of an organization with knowledge that it had been infiltrated by members of subversive groups under circumstances indicating that the individual was a part of, or sympathetic to, the infiltrating element or sympathetic to its purposes.

i. Participation in the activities of an organization, referred to in (d) above, in a capacity where he should reasonably have had knowledge of the subversive aims or purposes of the organization.

j. Sympathetic association with a member or members of an organization referred to in (d), or sympathetic interest in totalitarian, fascist, communist, or similar subversive movements.

k. Currently maintaining a close continuing association with a person who has engaged in activities or associations of the type referred to in (a) through (i). A close continuing association may be considered to exist if the individual lives at the same premises as, frequently visits, or frequently communicates with such person.

l. Close continuing association of the type described in (k) above, even though later separated by distance, if the circumstances indicate that renewal of the association is probable.

m. Any facts, other than as set forth in (n) through (s) below, which furnish reason to believe that the individual may be subjected to coercion, influence, or pressure which may cause him to act contrary to the best interest of national security. Among matters which should be considered in this category would be the presence of a spouse, parent, brother, sister, or offspring in a nation, a satellite thereof, or an occupied area thereof, whose interests are inimical to the interests of the United States.

n. Willful violation or disregard of security regulations.

o. Intentional unauthorized disclosure to any person of classified information, or of other information, disclosure of which is prohibited by law.

p. Any deliberate misrepresentation, falsification, or omission of material fact.

q. Any criminal, infamous, dishonest, immoral, or notoriously disgraceful conduct, habitual use of intoxicants to excess drug addiction, or sexual perversion.

r. Acts of a reckless, irresponsible or wanton nature which indicate such poor judgment and instability as to suggest that the individual might disclose security information to unauthorized persons or otherwise assist such persons, whether deliberately or inadvertently, in activities inimical to the security of the United States.

s. All other behavior, activities, or associations which tend to show that the person is not reliable or trustworthy.

t. Any illness, including any mental condition, of a nature which in the opinion of competent medical authority may cause significant defect in the judgment or reliability of the individual, with due regard to the transient or continuing effect of the illness and the medical findings in such case.

REVIEW AND SUMMARY

You have been introduced to some of the fundamentals of security. Remember what you have read and make security a part of your daily life. Be security conscious at all times. Report any violation or suspected violation of security. Do not be doubtful about security; if you are not sure about something concerning security, ask your leading petty officer or other competent person.

TOPIC 3: PUBLICATIONS

YOU ARE NOW GOING TO LEARN:

1. What types of publications you may use as an FT.
2. About keeping publications current.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Instructions and Notices.
2. NAVWEPS Publications.
   a. Equipment OP's.
   b. Specific OP's.
   c. OP-0.
   d. OD's.
   e. Newsletters.
3. Other Navy Department publications.
4. Keeping publications current.
5. Review and summary.

INFORMATION AND DISCUSSION:

The various bureaus of the Navy Department issue technical publications which are sources of important information for every man in the Navy. Publications by the Bureau of Naval Weapons, Bureau of Ships, Bureau of Supplies and Accounts, and the Bureau of Naval Personnel concern Fire Control Technicians. Publications are as important and necessary for keeping fire control equipment in top working order as hand tools and test equipment. Like hand tools and test equipment, publications must be properly used and maintained or they are no longer effective. Publications are frequently revised and it becomes necessary to make corrections to existing publications. A publication which is not kept current is as undesirable as a broken tool or a piece of test equipment which is not calibrated to assure correct readings. In the material which follows, you will be introduced to various types of publications you may use as an FT. You will also be introduced to the method of keeping publications current.

INSTRUCTIONS AND NOTICES

A system is in use throughout the Navy for the issuance of directive type releases, including those which prescribe policy, organization, methods or procedures, and those which contain information. Certain publications, such as established manuals, operation releases, technical publications, some classified matter, and those joint Army-Navy-Air Force publications which are numbered serially, but do not have separate Army or Air Force designations, are excluded from the system.

This program, called the Navy Directives System, provides a uniform plan for issuing and maintaining directives. Conformance to the system is required of all bureaus, offices, activities, and commands of the Navy. Two types of releases are authorized under the plan: Instructions and Notices.

Instructions are directives which contain information or require action of a continuing nature. An Instruction has permanent reference value and is effective until the originator supersedes or cancels it.

Notices are directives of a onetime nature and contain information or require action which can be completed immediately. A Notice does not have permanent reference value and contains provisions for its own cancellation.

For reasons of identification and accurate filing, all directives can be recognized by the originator's authorized abbreviation, the type of release (whether an Instruction or a Notice), a subject classification number and in the case of Instructions only, a consecutive number. Because of their temporary nature, the consecutive number is not assigned to Notices. This information is assigned by the originator and is placed on each page of the release. The manner of numbering and identifying directives can be better understood by considering a typical example:

BUWEPS	INST.	8260. 1
(a)	(b)	(c) (d)

(a) Here the authorized abbreviation of the originator of the directive is placed.
(b) This part refers to the type of release, in this case an Instruction.
(c) This is the subject number which is determined by the subject matter of the directive, and is obtained from the Table of Subject Classification Numbers.
(d) Following the period is the consecutive number which is found only on Instructions. An originator would assign consecutive numbers to those consecutive Instructions with the same subject classification number. In the example above, the subject classification number 8260 concerns Guided Missile Fire Control. If the originator, BUWEPS, issued additional Instructions dealing with guided missile fire control, they would be assigned numbers 8260.2, 8260.3, etc. Subject classification numbers are listed in the Table of Subject Classification Numbers found in SECNAV Instruction P5210.11. This table contains a numerical and alphabetical listing of numbers with their related subjects, and is of considerable value for reference use when information or instructions of a particular nature are desired. This Instruction contains all the necessary information for classifying documents by subject. The major numerical subject group, 8000-8999 - Ordnance Material is of interest to the FT.

NAVWEPS PUBLICATIONS

As an FT most of the publications you will use are NAVWEPS publications.

The primary source of technical information on operation, maintenance, adjustment, installation, and servicing of fire control equipment and other ordnance equipment is the Ordnance Pamphlet (OP) series of publications. OP's are of two categories: Equipment OP's and Specific Subject OP's.

Equipment OP's deal with specific ordnance equipment and are organized according to the following general outline:

1. Introduction
2. Theory and Functional Description
3. How to Operate the Equipment
4. Physical Description
5. Installation and Assembly
6. Maintenance
7. Overhaul and Repairs
8. Appendixes
9. Index
10. Safety Precautions

The Introduction gives a brief explanation of what equipment is, where it is used, what it is intended to do, and the like, as well as a description of differences among various modifications, if appropriate. One chapter may be devoted to each heading or, as is the case with more complex equipment, each topic may require an entire volume. You will find some variation as to arrangement of information within different OP's. For example, OP 2717 for Weapons Direction Equipment, Mk 4 Mod 0 consists of five volumes:

Vol. 1,	Physical Description
Vol. 2-1,	Functional Description
Vol. 2-2,	Functional Description
Vol. 3,	Installation Checks and Adjustments
Vol. 4-1,	Maintenance
Vol. 4-2,	Maintenance Diagrams - Servicing
Vol. 4-3,	Maintenance Diagrams - Servicing
Vol. 4-4,	Maintenance Diagrams - Units 001-091
Vol. 4-5,	Maintenance Diagrams - Units 101-190
Vol. 4-6,	Maintenance Diagrams - Units 191-351
Vol. 4-7,	Maintenance Diagrams - Tabular Wiring
Vol. 4-8,	Maintenance Diagrams - Tabular Wiring
Vol. 5,	Spare Parts

The Integrated Maintenance Plan (IMP) has been initiated by the Bureau of Naval Weapons to improve the maintenance techniques and maintenance documentation for missile weapon systems. All IMP publications will be arranged as follows:

Vol. 1,	Description and Operating Instructions
Vol. 2,	Scheduled Maintenance - Test and servicing procedures categorized by frequency of performance.
Vol. 3,	Trouble Isolation - All material required for trouble isolation after equipment has failed a scheduled test.
Vol. 4,	Corrective Maintenance - Procedures for the alignment, adjustment, calibration, repair, and replacement of subassemblies.
Vol. 5,	Replaceable Parts List.

Specific Subject OP's deal with a subject area rather than a specific item of ordnance equipment. These OP's will not follow the outline of equipment OP's. Specific Subject OP's such as NAVWEPS OP-3000 "Weapons Systems Fundamentals" are written as references for instruction and training.

A specialized OP which you will find very valuable is OP-0. This is a listing of all types of ordnance publications. It consists of several separate parts; each part contains related material and is capable of being revised or expanded independent of the remaining parts. Parts are arranged in the following order:

Part 1 - NAVWEPS OP Technical Manuals

Section A - A Numerical Locator portion which indicates the status (current, under preparation, or obsolete) of all NAVWEPS OP numbers alloted up to and including the issue date of OP-0 itself. (The present OP-0 is the 34th revision dated 15 December 1964.)

Section B - The Cog-I Stock Publications section lists publications available from the Naval Supply Depot, Philadelphia, Pa., and contains the title, current revision, latest change, and the cognizant technical desk. (Publications shall not be ordered from the cognizant technical desk.) Titles of obsolete publications are not included in this section. The Numerical Locator should be checked to determine if a publication is obsolete or superseded.

Section C - Lists Non Cog-I current publications stocked at locations other than the stock point for Cog-I NAVWEPS OP publications. These publications are itemized under each stocking point.

Section D - Contains publications presently under preparation, listed with an estimated completion date, security classification, and the Cog Desk.

Section E - Is a cross-reference of NAVWEPS OP Technical manuals and their related Ordnance Supply Office (OSO), and prepared Illustrated Parts Breakdown (IPB's) manuals.

Part 2 - NAVWEPS Ordnance Data Publications (OD's). This part consists of the following sections:

Section A - A Numerical Locator portion which indicates the status (current, under preparation, or obsolete) of all NAVWEPS OD numbers alloted up to and including the issue date of OP-0.

Section B - The CTDO Stock Publications section lists current publications stocked at the Central Documents Office, U. S. Naval Ordnance Plant, Louisville, Kentucky.

Section C - This section lists current NAVWEPS OD publications available from sources other than the major stock points.

Part 3 - Miscellaneous Indexes. This part contains an index for General Publications, Surface Missile Systems, Mine Systems, ASROC Publications, and NAVORD charts. It is the intention to include additional special indexes of this type in the future.

Part 4 - Subject Index. Part 4 is a Subject Index of all NAVWEPS OP's and OD's listed in this publication, under equipment identification.

Ordnance Data publications (OD's) will also be valuable to you as an FT. OD's contain routine test and inspection results, installation and alignment data, parallax data, publications required lists, and ordnance equipment lists.

OD 9398, "Fire Control Maintenance Notes", is published as a series of volumes. Each volume is concerned with a specific fire control system. The notes are often an important source of information for maintenance. A maintenance note will "point a finger" at a trouble which occurs commonly. You will find these notes available aboard ship. You should read the maintenance notes for your specific equipment and refer to them if you encounter a particularly complex problem. Some other technician may have encountered the same trouble, and if so, the solution may be in the notes.

Newsletters - Another type of BUWEPS publication you may find useful is the Newsletter. Newsletters are published for the Talos, Tartar, and Terrier Missile Systems. Newsletters are intended to serve the need for rapid dissemination of official BUWEPS approved technical information about equipments, doctrine, testing techniques, and performance characteristics of the missile systems. Much of the mateiral in the Newsletters will be subsequently incorporated in the systems and equipment OP's and Maintenance Notes.

OTHER NAVY DEPARTMENT PUBLICATIONS

You have been introduced to various publications of the Bureau of Naval Weapons. As an FT, you will also use publications of various other Bureaus.

The Trainee's Guides you will use in this school are NAVPERS Publications. Correspondence courses such as "Basic Military Requirements", "Seaman", and "Fire Control Technician 3" are also NAVPERS publications. You will find, if you desire to advance in rate, certain correspondence courses are required before you may take the examination for advancement in your rating. NAVPERS publications also cover many related subjects that will allow you to broaden your knowledge in the field of fire control and electronics.

As an FT, you will also use NAVSHIPS publications. FT's are responsible for three-coordinate search radars as well as other equipments which are under cognizance of the Bureau of Ships. The publications concerning these equipments will be NAVSHIPS publications.

As part of your job you will also have need for information concerning replacement parts, tools, test equipment, and other miscellaneous items. Much of this information will be found in Bureau of Supplies and Accounts (BUSANDA) publications.

KEEPING PUBLICATIONS CURRENT

As stated earlier, publications must be kept current or they are no longer effective. There are several reasons why publications must be changed:

1. Correction of errors in the original publication.

2. Clarification of certain explanations.

3. Changes of test procedures.

4. Modifications to equipment.

When a change is to be made in a publication, the cognizant Bureau will distribute change notices to holders of the publication. The change notice will contain instructions for making the required change. It is essential that all instructions be carefully followed. Some changes will require replacement of pages and others will call for handwritten corrections or a combination of the two. You must be sure to make all corrections properly. The publication itself will either have a page to list all changes made or a title page which shows the latest revision.

Modification of the equipment in the form of ORDALTS or SHIPALTS, (Alterations to ordnance equipment and equipment under cognizance of BUSHIPS), may also require changes in the equipment publication. The instructions for completion of the alteration will also contain instructions for changing the publication. The alteration is not properly completed until the changes to the publication are made as well as changes to the equipment.

REVIEW AND SUMMARY

A very important item for you to remember is: When you are working on fire control equipment, make it a rule to have the applicable OP with you for ready reference. Applicable means that the OP is for the equipment you have, including any modifications, and has been kept current by addition of all existing changes.

Two particular publications which you will find especially useful are: OP-0 "Index of Bureau of Naval Weapons Ordnance Publications" and OD 9398 "Fire Control Maintenance Notes".

QUIZ:

1. What is the meaning of Fire Control?

2. Your job as an FT will include the ______________and ____________ of various fire control equipments.

3. Beside your occupational or professional duties, you will also have certain ______________________duties.

4. Define "director firing".

5. What is the definition of a guided missile?

6. As an FT you will most likely be assigned to what department aboard ship?

7. The 0800 - 1200 watch is called the _________________watch.

8. The second "dog" watch is from _______________to _______________

9. List and define the four conditions of battle readiness.

10. What is OPNAVINST 5510.1B?

11. With respect to security, define:
    a. Compromise
    b. Need to Know
    c. Confidential
    d. Secret
    e. Top Secret

12. With respect to Navy publications, define:
    a. Instructions
    b. Notices

13. What is OP-0, and what type of information does it contain?

14. What is OD-9398, and why will it be important to you?

15. What are ORDALTS?

16. What must be done to an OP when an ORDALT is installed?

Section 2

THE FIRE CONTROL PROBLEM

Topic No.	Topic Title	Page
1.	Mechanics of the Fire Control Problem	38
2.	Solving the Fire Control Problem.	78

TOPIC 1: MECHANICS OF THE FIRE CONTROL PROBLEM

YOU ARE NOW GOING TO LEARN:

1. Mathematics required to solve the fire control problem.
2. Standard fire control symbols.
3. Factors which affect the fire control problem.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Mathematics.
    a. Sign numbers.
    b. Fractions and decimals.
    c. Exponents and radicals.
    d. Algebra.
    e. Trigonometry.
    f. Vectors.
2. Standard fire control symbols.
    a. Introduction to OP 1700.
    b. Symbols and modifiers.
    c. Coordinate systems.
3. Interior ballistics.
4. Exterior ballistics.
    a. Effects of gravity.
    b. Effects of air resistance.
    c. Effects of drift.
    d. Effects of wind.
    e. Effects of relative motion.
    f. Effects of deck motion.
    g. Effects of target elevation.
5. Review and summary.

ASSIGNMENT:

A. Reference publication:

    1. Study OP 1700, Standard Fire Control Symbols, pages 1 to 9.

INFORMATION AND DISCUSSION:

A requirement of every FT, is a thorough working knowledge of the fire control problem. Your first question is undoubtedly, "What is the fire control problem?". In answer to your question, it may be stated that there are several "fire control problems". The most generalized statement of the fire control problem is: How can any weapon be directed such that it will cause destruction of the selected target. To further amplify this statement, let us say that a slightly different problem exists for different types of targets (aircraft, surface ship, submarine, etc.). Location of the weapon (ship, shore, etc.) will also change the problem. The fundamental problem as far as most of you will be concerned is -- how can a ship, underway or dead-in-the-water, destroy a stationary or moving target. Many of the factors involved are common to more than one variation of the problem. In the material which follows, the emphasis will be on gun fire control problems. As an aid to understanding the problem, you will study the mathematics required to solve the problem, the symbols used to denote the various quantities, and the various factors which affect the problem.

MATHEMATICS

The mathematics required for solving the fire control problem is not difficult and many of you may have already learned all of the mathematics required, however, in the material which follows we will review some of the fundamentals of the mathematics which you will need to know in order to solve the fire control problem. Not only will you use this mathematics to solve the fire control problem; you will also use it in all other phases of fire control.

SIGN NUMBERS

In the mathematics which you will use in fire control, the concept of "direction sense" of a number is very important. In introducing "direction sense", zero (0) is normally considered as the reference point. Numbers preceded by a (-) have a negative direction and numbers preceded by a (+) have a positive direction. Such a series of numbers is shown as follows:

.. -4, -3, -2, -1, 0, +1, +2, +3, +4 ..

As an example of how you may use sign numbers, consider your ship on the surface of the ocean to be at the zero reference. An airplane at 5000 feet has a height of +5000 and a submarine 150 feet below the surface has a height of -150. If the reference is now shifted to the airplane, the height of the airplane is 0, the height of your ship is -5000 feet, and the height of the submarine is -5150.

If you remember the following definitions and rules, you will not have any trouble with sign numbers.

Addition:

Definition: The symbol for addition is (+), the numbers to be added are the addends, and the result is the sum.

Rules:

1. For terms with like signs, sum the absolute values and affix the common sign. For example:

   $$7 + 4 = 11$$

   $$(-4) + (-6) = -10$$

2. For terms with unlike signs, take the difference of the absolute values and affix the sign of the larger. For example:

   $$4 + (-7) = -3$$

   $$9 + (-7) = 2$$

Subtraction:

Definition: The symbol for subtraction is (-), the first number is the minuend, the number being subtracted is called the subtrahend, and the answer is called the difference or remainder.

Rule: The process of subtraction becomes much easier when the operation is changed to addition, therefore, change the sign of operation and the sign of the subtrahend and proceed as in addition. For example:

$$(-4) - (-6) = (-4) + (6) = 2$$

$$(-6) - (\ 6) = (-6) + (-6) = -12$$

Multiplication:

Definition: The basic symbol for multiplication is (x), however, several other means will often be used to indicate multiplication. For example:

$$2 \times 4 \quad \text{or} \quad 2 \cdot 4 \quad \text{or} \quad (2)(4)$$

The numbers being multiplied are called the multiplicand and the multiplier, and the answer is the product.

Rules:

1. For terms with like signs, find the product of the absolute values and affix a (+) sign. For example:

   $$2 \times 3 = 6$$

   $$(-4)(-4) = 16$$

2. For terms with unlike signs, find the product of the absolute values and affix a (-) sign. For example:

   $$(-7)(2) = -14$$

Division:

Definition: The symbol for division is (÷), the numbers are the divisor and the dividend (the dividend is divided by the divisor), and the answer is the quotient.

Rules:

1. For terms with like signs, find the quotient of the absolute values and affix a (+) sign. For example:

$$\frac{4}{2} = 2$$

$$(-8) \div (-2) = 4$$

2. For terms with unlike signs, find the quotient of the absolute values and affix a (-) sign. For example:

$$(-16) \div (4) = -4$$

FRACTIONS AND DECIMALS - The numbers considered up to now have been whole numbers. Many times it is necessary to indicate a partial number. One means of doing this is the fractional method (3/4) and the other is the decimal method (.75). Sometimes for the sake of accuracy, the fractional method is the best because it is impossible to derive a number exactly by the decimal method. For example:

$$\frac{2}{3} \times 30 = 20$$

but

(.666...) x 30 will never be exactly equal to 20. Note that the decimal is found by dividing the numerator by the denominator.

The rules which apply to signs of whole numbers also apply to fractions and decimals. Some special considerations are involved in dealing with either fractions or decimals. They will be illustrated in the examples which follow.

Fractions: In the fraction 3/4, the 3 is the numerator and the 4 is the deniminator. Before fractions may be added or subtracted, the denominators must be the same. For example:

$$\frac{1}{2} + \frac{2}{3} + \frac{3}{4}$$

The first step is to find the least common denominator, LCD, (lowest number which is a whole multiple of each of the denominators), in this case 12. The next step is to convert each of the fractions to an equal fraction whose denominator is 12. Thus, 1/2 = 6/12, 2/3 = 8/12, and 3/4 = 9/12. The next step is to sum the numerators, place the sum over the LCD and reduce the resulting fraction to its lowest form.

$$\frac{6 + 8 + 9}{12} = \frac{22}{12} = 1\frac{5}{6}$$

Multiplication of fractions is a simple matter of finding the products of the numerators and denominators and reducing the fraction. For example:

$$\frac{2}{3} \times \frac{3}{4} = \frac{6}{12} = \frac{1}{2}$$

Division of fractions is easily accomplished by inverting the denominator fraction and multiplying it by the numerator fraction. For example:

$$\frac{2}{3} \div \frac{2}{5} = \frac{2}{3} \times \frac{5}{2} = \frac{10}{6} = 1\frac{2}{3}$$

It should be noted that a negative number is never left in the denominator. The negative denominator may be removed by multiplying both the numerator and the denominator by a -1. For example:

$$\frac{1}{-2} \times \frac{3}{4} = \frac{3}{-8}$$

$$\frac{3\ (-1)}{(-8)(-1)} = \frac{-3}{8}$$

Decimals: Operations involving decimals follow the rules for sign numbers and the only thing to watch is the placement of the decimal point. This will be illustrated in the following examples.

Addition:

.509 + 9.25 + 1.001

Place the numbers in columns with the decimal points aligned. Now sum the columns. There must be as many digits to the right of decimal point in the answer as there is in any of the numbers which are being added. The last digit may be a 0 which is normally dropped after placing of the decimal point.

Thus,

$$\begin{array}{r} .509 \\ 9.25 \\ \underline{1.001} \\ 10.760 \end{array} \quad \text{or} \quad 10.76$$

The same method is used for subtraction.

Multiplication:
The product is found by multiplying the absolute values of the numbers and placing the decimal point according to the following rule: The number of digits to the right of the decimal point in the product must be equal to the sum of the number of digits to the right of the decimal point in the multiplicand and the multiplier. For example:

$$.75 \times .5 = .375$$

$$7.5 \times 5 = 37.5$$

It may be necessary to add zeros between the decimal point and the other digits in order to obtain the number of required positions. For example:

$$.1 \times .07 = .007$$

Division:
The first step is to make the divisor a whole number by moving the decimal point to the right. The next step is to move the decimal point of the dividend the same number of digits and proceed with normal division. Note that it may be necessary to add zeros to the dividend to obtain the required number of decimal positions. For example:

$$\begin{array}{r|l} & 7\,021.6 \\ \hline .025. & 175.540.0 \\ & \underline{175} \\ & \quad 54 \\ & \quad \underline{50} \\ & \qquad 40 \\ & \qquad \underline{25} \\ & \qquad 150 \\ & \qquad 150 \end{array}$$

EXPONENTS AND RADICALS - Many of the problems you will have to solve in fire control will involve exponents and radicals. Before the various rules for dealing with exponents and radicals are presented, a few terms will be defined.

Base, exponent, and power - Raising a number to a power is a special case of multiplication in which the factors are all equal. For example:

$$5^3 = 5 \times 5 \times 5 = 125$$

In the example, 5 is the base, 3 is the exponent which indicates the number of times the base is multiplied by itself, and 125 is the third power of 5.

Root: The inverse operation of raising a number to a power is finding a root of a number. This consists of finding one of the equal factors of a number. For example:

$3^2 = 9$ and $(-3)^2 = 9$, thus both +3 and -3 are square roots of 9.

Radical sign: The desired root of a number can be indicated by placing a radical sign ($\sqrt{\ }$) over the number and showing the root desired by placing a small number within the crook of the radical sign. A radical sign by itself means the square root. For example:

$\sqrt{16} = \pm 4$ (Both +4 and -4 are square roots of 16)

$\sqrt[3]{8} = 2$ (The cube root of 8 is +2)

$\sqrt[4]{16} = \pm 2$ (Both +2 and -2 are fourth roots of 16)

Laws of Exponents: You will have very little difficulty with exponents if you remember the simple laws which follow:

Multiplication:
To multiply two or more powers having the same base, add the exponents and raise the common base to that power. For example:

$$2^2 \times 2^3 = 2^{(2+3)} = 2^5 = 2x2x2x2x2 = 32$$

Division:
In division of powers of the same base, the exponent of the quotient equals the exponent of the dividend minus the exponent of the divisor. For example:

$$\frac{6^5}{6^3} = 6^{(5-3)} = 6^2 = 36$$

$$\frac{5^3}{5^2} = 5^{(3-2)} = 5^1 = 5$$

Note that any number raised to the first power is equal to the number itself. The exponent 1 is usually not written but is understood.

$$\frac{3^2}{3^2} = 3^{(2-2)} = 3^0 = 1$$

Note that any base raised to the 0 power is equal to 1.

$$\frac{7^3}{7^4} = 7^{-1} = \frac{1}{7}$$

$$\frac{3^4}{3^6} = 3^{(4-6)} = 3^{-2} = \frac{1}{3^2} = \frac{1}{9}$$

Note that a number with a negative exponent is equal to 1 divided by the same number with a positive exponent, the absolute value of which is equal to the negative exponent.

Power of a Power:

To find the power of a power, multiply the exponents. For example:

$$(2^2)^3 = 2^6 = 64$$

The proof of this can be seen if you remember that an exponent indicates the number of times a number is multiplied by itself. Thus,

$$(2^2)^3 = (2^2)(2^2)(2^2) = 4 \text{x} 4 \text{x} 4 = 64$$

Powers of Ten: Many of the problems you will solve as an FT, will have numbers which are either very large or very small. Use of the concept of powers of ten will simplify the calculations. There is nothing new or complicated about this concept; it simply makes use of a few rules which you have already studied. First of all you must consider that any number may be expressed as the product of two other numbers, i.e., 25 may be thought of as 5 x 5, 2 x 12.5, or 2.5 x 10. In using powers of ten, we will always consider 10 or the base 10 raised to some power as one of the numbers. Before you go any further, consider the base ten raised to various powers. When you apply the laws of exponents, you will find:

$$\begin{array}{ll}
10^{-1} = .1 & 10^4 = 10000 \\
10^{-2} = .01 & 10^3 = 1000 \\
10^{-3} = .001 & 10^2 = 100 \\
10^{-4} = .0001 & 10^1 = 10 \\
10^{-5} = .00001 & 10^0 = 1
\end{array}$$

Now consider the following problem:

$$X_L = 2 \text{ x } 3.14 \text{ x } 20000 \text{ x } .000007$$

The calculations are simplified if you use powers of ten. Thus, 20000 is $2 \text{x} 10^4$, and .000007 is $7 \text{x} 10^{-6}$. The problem is now:

$$X_L = 2 \text{ x } 3.14 \text{ x } 2 \text{ x } 10^4 \text{ x } 7 \text{ x } 10^{-6}$$

$$= 87.92 \text{ x } 10^{-2} \text{ or since } 10^{-2} = .01$$

$$X_L = .8792$$

Another typical problem is:

$$X_C = \frac{1}{2 \text{ x } 3.14 \text{ x } 10000000 \text{ x } .000000000002}$$

$$X_C = \frac{1}{2 \text{ x } 3.14 \text{ x } 1 \text{ x } 10^7 \text{ x } 2 \text{ x } 10^{-12}}$$

$$X_C = \frac{1}{12.56 \text{ x } 10^{-5}} = .79 \text{ x } 10^4$$

$$X_C = 7900$$

To determine the power of ten of any number, you must remember the following:

1. To find the power of ten of any number greater than 1, move the decimal point to the left such that only one digit remains to the left of the decimal point. The number of places the decimal point is moved is the (+) power of ten. For example:

$$1739.82 = 1.73982 \text{ x } 10^3$$

2. To find the power of ten of any number less than 1, move the decimal point to the right until one digit other than zero is to the left of the decimal point. The number of places the decimal point is moved is the (-) power of ten. For example:

$$.00000639 = 6.39 \times 10^{-6}$$

Fractional Exponents: Whereas whole number exponents were used to indicate the power of a number, a fractional exponent is used to indicate the root of a number. For example:

$$4^{\frac{1}{2}} = \sqrt{4}$$

$$125^{\frac{1}{3}} = \sqrt[3]{125}$$

The denominator of the fractional exponent indicates the index of the root (square root, cube root, etc.) and the numerator indicates the power of the number.

Radicals: You have already learned what a radical is. You will now learn the rules which govern operations with radicals. One of the first things you must remember when finding roots of a number is that an even root (square root, fourth root, etc.) may be either plus or minus. For example:

$\sqrt{9} = \pm 3$ since $3 \times 3 = 9$ and $-3 \times -3 = 9$

Combining radicals: In the expression $7\sqrt[3]{8}$, 7 is the coefficient, 3 is the index, and 8 is the radicand. Radicals with the same index and radicand are similar. Radicals with the same index are said to be of the same order. Operations with radicals follow the rules of sign numbers, however, a few additional rules must be observed.

Addition and Subtraction:
Radicals may be added or subtracted if they are similar. For example:

$$7\sqrt{3} + 8\sqrt{3} = 15\sqrt{3}$$

$$9\sqrt{7} - 6\sqrt{7} = 3\sqrt{7}$$

$7\sqrt{8} + 6\sqrt[3]{8}$ cannot be combined in radical form because the index is different. $7\sqrt{8} + 6\sqrt{3}$ cannot be combined in radical form because the radicands are different.

Multiplication and Division:
Radicals of the same order may be multiplied or divided. For example:

$$\sqrt{3} \cdot \sqrt{2} = \sqrt{6}$$

$$\frac{\sqrt{15}}{\sqrt{5}} = \sqrt{3}$$

Simplifying radicals: Many times it will make a problem easier to solve if radicals can be simplified. A radical is in its simplest form when no factor can be removed from the radical, when there is no fraction under the radical sign, and when the index of the root cannot be reduced.

Removing a Factor:
A factor can be removed from the radical if it occurs a number of times equal to the index. For example:

$$\sqrt{50} = \sqrt{25 \times 2} = \sqrt{5^2 \times 2} = 5\sqrt{2}$$

Eliminating Fractions under a Radical: In some problems you may be required to find a root of a fraction. The normal procedure is to eliminate the fraction under the radical before the root is found. For example:

$$\sqrt{\frac{1}{4}} = ?$$

In this simple problem you may recognize that the answer is ±1/2, however, in some cases you may not recognize the root. In cases of this type you will follow the procedure which follows:

$$\sqrt{\frac{1}{3}} \text{ may be written as } \frac{\sqrt{1}}{\sqrt{3}}$$

If you now consider only the positive root, you will have $1/\sqrt{3}$. At this point we will stop and define rational and irrational numbers.

A number is rational when it can be expressed as the quotient or ratio of two whole numbers. Rational numbers include fractions like 3/4, whole numbers, and radicals if the radical sign is removable. Any whole number is rational since it can be expressed as a quotient by dividing by 1. For example: 4/1. Likewise $\sqrt{16}$ is rational since it also can be expressed as 4/1 or -4/1.

A number which cannot be expressed as the ratio of two whole numbers is irrational. For example:

$$\sqrt{2}, \quad 7\sqrt{3}, \text{ and } \frac{1}{\sqrt{5}}$$

You should now be prepared to return to the problem $\sqrt{1}/\sqrt{3} = ?$ The next step in solving this problem is to rationalize the denominator. This is done by multiplying both the numerator and denominator by the radical which will remove the denominator radical, i.e., $\frac{\sqrt{1}}{\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}} = \frac{\sqrt{3}}{3}$.

To complete the solution, if further simplification is called for, you must find the square root of 3 and divide by 3. There are several ways in which you may find the square root of 3. One way of finding the root is by use of a root table. If you do not have a root table, you can calculate the root by the following method:

Find the square root of 27348.29

1. Mark off the number in sets of two from the decimal point.

```
2 73 48 . 29
```

2. Find the highest square in the first group.

```
 1
|2 73 48 . 29
```

3. Square the 1, place it under the 2 and subtract. Carry down the next group.

```
 1
|2 73 48 . 29
 1
 173
```

4. Double that part of the root already found (1) and place it in front of the 173. Now find a new number such that the product of this number and the two digit number, formed by placing the new number after the 2, is less than 173. (This is mostly a process of trial and error.) Place the product under the 173 and subtract.

```
          1  6
         |2 73 48 . 29
          1
26        173
          156
           17
```

5. Carry down the next group of numbers and proceed as in step 4.

```
          1  6  5
         |2 73 48 . 29
          1
26        173
          156
325        1748
           1625
            123
```

6. Continue the process until the required number of digits after the decimal point are obtained. It may be necessary to add groups of zeros.

```
          1  6  5 .  3  7
         |2 73 48 . 29 00
          1
26        173
          156
325        1748
           1625
3303        12329
             9909
33067       242000
            231469
             10531          This is a
                            remainder
```

A check on the problem is to square 165.37 and add the remainder to the square.

```
      165.37
      165.37
     115759
     49611
    82685
   99222
  16537
  27347.2369
      1.0531
  27348.2900
```

ALGEBRA - The branch of mathematics which treats the relations and properties of numbers by means of letters, signs of operation, and other symbols is called algebra. In fire control you will use algebra to solve various equations in order to determine unknown quantities.

The basic laws which govern operations in arithmetic also apply to algebraic operations:

Commutative Law of Addition:
The sum of two or more addends is the same in whatever manner the addends are arranged. For example:

$$a + b + c = b + c + a = c + a + b$$

Associative Law of Addition:
The sum of three or more addends is the same in whatever manner they are grouped. For example:

$$a + b + c = (a + b) + c = a + (b + c)$$

Commutative Law of Multiplication:
The product of two or more factors is the same in whatever manner the factors are arranged. For example:

$$abc = bac = cba = bca = cab$$

Associative Law of Multiplication:
The product of three or more factors is the same in whatever manner the factors are grouped. For example:

$$a \cdot b \cdot c = (a \cdot b)c = a(b \cdot c)$$

Distributive Law of Multiplication:
If the sum or difference of two or more numbers is multiplied by a third number, the product may be found by multiplying each of the numbers separately by the multiplier and connecting the results by the proper signs. For example:

$$a\,(b + c - d) = ab + ac - ad$$

Before you proceed, some of the terminology of algebra will be defined:

Algebraic expression: A combination of the signs and symbols of algebra which represent one number or quantity. For example:

$$a - b,\ X,\ ab,\ x/y,\ \text{and}\ \frac{a - 2b}{3}$$

Terms: The parts of an algebraic expression separated by + or - signs are called terms. For example:

In the expression $x^2y - 3xy^2 + y^3$, x^2y, $3xy^2$, and y^3 are all terms.

Coefficient: Any factor or group of factors of a term by which the remainder of the term is to be multiplied is called the coefficient. Thus, in the term 2xyz, 2xy is the coefficient of z, 2x is the coefficient of yz, and 2 is the coefficient of xyz. The 2 is the numerical coefficient and the algebraic symbols are literal coefficients. Normally the word coefficient is limited to mean the numerical coefficient.

Similar terms: Terms are similar if they contain the same literal factors effected by the same exponents. Similar terms may be combined. For example:
$7x^2yz - 3x^2yz = 4x^2yz$ but x^2yz cannot be combined with xyz because the exponent of x is not the same.

Monomial: An algebraic expression of only one term.

Binomial: An algebraic expression of two terms.

Trinomial: An algebraic expression of three terms.

Polynomial: Any algebraic expression containing two or more terms may be called by the general name, polynomial.

Now that some of the terminology has been defined, we will proceed with some of the operations:

Order of Operations:
Many times it will be necessary to perform two or more operations in an equation. It is

also necessary that one operation be performed before the other. For example: In the problem A x B - C x D, the question arises as to which operation should be performed first. If you substitute the values A = 2, B = 3, C = 4, and D = 5, and do the subtraction first, you will find 2 x (3 - 4) x 5 = -10. On the other hand, if the multiplication is performed first, you will find (2 x 3) - (4 x 5) = -14. In situations such as this, the rule is: Perform the operations in the sequence of: Multiplication, division, addition, and subtraction.

A method of eliminating the confusion is to group the terms of individual operations with symbols. The symbols and order of operation are: The vinculum ——, the parenthesis ( ), the brackets [ ] , and the braces { } . Extreme caution must be used when removing the signs of operation. The operations within the symbols are performed and then the symbol removed in the order of operation. For example:

$$\{[8 + (4) \times 6-3 -9] \times [6+3]\} + \{5\} =$$

Removing the vinculum -

$$\{8 + [(4) \times (3) -9] \times [6+3]\} + \{5\} =$$

Removing the parenthesis -

$$\{8 + [12 - 9] \times [6 + 3]\} + \{5\} =$$

Removing the brackets - Note parenthesis added when brackets removed.

$$\{8 + (3 \times 9)\} + \{5\} =$$

Removing the braces -

$$35 + 5 = 40$$

Multiplying Monomials:

The product is found by multiplying the numerical coefficients to form the coefficient of the product and multiplying the literal symbols to form the literal part. The rules of signs must be observed. For example:

$$(3xy) \quad (6ax) = 18ax^2y$$

$$(3a^2b) \quad (7ab) \quad (-7ac) = -147a^4b^2c$$

Dividing Monomials:

The quotient is found by dividing the numerical coefficients and canceling the common literal factors in the dividend and divisor. You will note that canceling is the same as dividing. For example:

$$6xy \div 3x = \frac{\overset{2}{\cancel{6x}}y}{\cancel{3x}} = 2y$$

$$\frac{\overset{2x^2y}{\cancel{8x^3y^2}}z}{\cancel{4xy}} = 2x^2yz$$

Operations with Polynomials:

Addition or subtraction of polynomials is a simple matter of combining like terms and connecting the results with the proper signs For example: Add 5x + 6xy + 7y to 3x - 3xy + 6y.

$$\begin{array}{r} 5x + 6xy + 7y \\ 3x - 3xy + 6y \\ \hline 8x + 3xy + 13y \end{array}$$

Subtract $7x^2 - 3x + 8$ from $9x^2 - x + 9$

$$\begin{array}{r} 9x^2 - x + 9 \\ -7x^2 + 3x - 8 \\ \hline 2x^2 + 2x + 1 \end{array}$$

Note that all signs of the subtrahend were changed and the problem completed as addition.

Multiplication of Polynomial by Monomial:

Multiply each term of the polynomial by the monomial. For example:

$$2a\ (x^2 + a + 1) = 2ax^2 + 2a^2 + 2a$$

Multiplication of a Polynomial
by a Polynomial:

Multiply each term of one polynomial by each term of the other polynomial and add algebraically. For example:

$$(2a^2 + a + 9) \quad (a - 3) =$$

$$2a^3 + a^2 + 9a - 6a^2 - 3a - 27 =$$

$$2a^3 - 5a^2 + 6a - 27$$

Division of a Polynomial by a Monomial: Division of this type is similar to division of monomial by monomial. For example:

$$3x^2y - xy + x \div x$$

Note that the problem can be rewritten as three monomial divisions connected by the proper signs.

$$\frac{3x^2y}{x} - \frac{xy}{x} + \frac{x}{x} = 3xy - y + 1$$

Division of a Polynomial by a Polynomial: The following procedure is used:

1. Arrange both the dividend and the divisor in either descending or ascending powers of the same letter.
2. Divide the first term of the dividend by the first term of the divisor and write the result as the first term of the quotient.
3. Multiply the complete divisor by the quotient just obtained, write the terms of the product under the like terms of the dividend, and subtract this expression from the dividend.
4. Consider the remainder obtained in step 3 as a new dividend and repeat steps 1, 2, and 3. For example:

$$15x^3 - 7x^2y + 26xy^2 - 24y^3 \div 5x - 4y$$

$$\begin{array}{r|r}
 & 3x^2 + xy \quad + 6y^2 \\ \cline{2-2}
5x - 4y & 15x^3 - 7x^2y + 26xy^2 - 24y^3 \\
 & 15x^3 - 12x^2y \qquad\qquad\qquad\quad \\ \cline{2-2}
 & 5x^2y + 26xy^2 \qquad\quad \\
 & 5x^2y - 4xy^2 \qquad\quad \\ \cline{2-2}
 & 30xy^2 - 24y^3 \\
 & 30xy^2 - 24y^3 \\ \cline{2-2}
\end{array}$$

Answer - $3x^2 + xy + 6y^2$

Factoring:
The factors of a polynomial are two or more expressions which when multiplied together give the polynomial as a product. For example:

$7x$ and $(x + 4)$ are factors of $7x^2 + 28x$

An algebraic expression is a prime factor if it contains no other factors except itself and 1. Monomial factors such as 3x are not prime factors, however, they are normally not separated. The process of separating an algebraic expression into its prime factors is called factoring.

Factoring is mainly a process of trial and error, however, there are several basic steps which will simplify the process. The first step is to remove any monomial factor which is common to each term of the expression. In selection of the monomial factor, as many factors as possible should be removed. For example: $3abx + 6ax = 3ax(b + 2)$. Note that if only 3a had been selected as the monomial, the remaining expression $(bx + 2x)$ would still contain a common factor, (x). The next step is to try and recognize certain types of products such as the square of a sum or difference. For example:

$(x - y)^2 = x^2 - 2xy + y^2$ and $(x + y)^2 = x^2 + 2xy + y^2$.

Many times the algebraic expression must be rearranged before the factors are easily recognized. Once the expression has been reduced to a trinominal which is not recognized as a special product, you will have to resort to trial and error. For example:

$x^2 + 13x + 40 = ?$ At this point, you can start the process by writing the parenthesis and placing the common term in each. $(x \quad ?) \quad (x \quad ?)$. The next step is to find two numbers, the product of which is 40 and the sum of which is 13. Since both the second and third terms are (+) in the original expression, you know the numbers you want a are both (+). In this case, $5 \times 8 = 40$, and $5 + 8 = 13$, therefore the factors are: $(x + 5)(x + 8)$. Practice is the only way to develop skill in factoring.

Algebraic Fractions:

The rules which applied to fractions which contained only arithmetic numbers also apply to algebraic fractions. One of the first steps in simplifying algebraic fractions is to factor and cancel terms which are common to both the numerator and the denominator. For example:

$$\frac{\cancel{3}x^{\cancel{2}}\cancel{y}}{\underset{2}{\cancel{6}}\cancel{xy}z} = \frac{x}{2z}$$

Addition and Subtraction:

After the fractions have been simplified by factoring and canceling, the L. C. D. must be found. The L. C. D. will contain all of the various prime factors, each one as many times as it occurs in any of the denominators. For example:

$$\frac{4x}{x^3 - 4x} + \frac{3x}{x^3 - 4x^2 - 12x}$$

Simplifying and canceling -

$$\frac{4x}{x(x \quad - 4)} + \frac{3x}{x(x \quad - 4x - 12)}$$

Factoring -

$$\frac{4}{(x - 2)(x + 2)} + \frac{3}{(x - 6)(x + 2)}$$

Using L. C. D. and combining -

$$\frac{4(x - 6) + 3(x - 2)}{(x - 2)(x + 2)(x - 6)} = \frac{4x - 24 + 3x - 6}{\text{L. C. D.}}$$

$$= \frac{7x - 30}{(x - 2)(x + 2)(x - 6)} = \frac{7x - 30}{x^3 - 6x^2 - 4x + 24}$$

Multiplication:

The first step is to simplify the fractions by factoring and canceling where possible. The product is then found by multiplying the numerators and the denominators. For example:

$$\frac{x^2 - 2x + 1}{x^2 - 9} \cdot \frac{x^2 + x - 6}{x^2 - 1}$$

Factoring and canceling -

$$\frac{(x - 1)\cancel{(x - 1)}}{(x - 3)\cancel{(x + 3)}} \cdot \frac{\cancel{(x + 3)}(x - 2)}{\cancel{(x - 1)}(x + 1)} =$$

$$\frac{(x - 1)(x - 2)}{(x + 1)(x - 3)} = \frac{x^2 - 3x + 2}{x^2 - 2x - 3}$$

Division:

The quotient is found by factoring, inverting the divisor, canceling, and proceeding as with arithmetic fractions. For example:

$$\frac{x - 3y}{x + 3y} \div \frac{x^2 - 6xy + 9y^2}{x^2 + 7xy + 12y^2} =$$

$$\frac{\cancel{x - 3y}}{\cancel{x + 3y}} \cdot \frac{\cancel{(x + 3y)}(x + 4y)}{\cancel{(x - 3y)}(x - 3y)} = \frac{x + 4y}{x - 3y}$$

EQUATIONS - In your career as an FT, you will use algebra in solving various equations. An equation is a statement that two expressions are equal. Thus, $5 + 7 = 12$, and $E = IR$ (Ohm's Law) are equations. For the most part, the problems you will be required to solve will involve manipulation of various formulas in order to determine unknown quantities. If you remember the following basic rule, you should have very little trouble in manipulating formulas to suit your need.

If both members (terms on either side of the equal sign are referred to as the left and right members) of an equation are increased, decreased, multiplied, or divided by the same number, the results will be equal. (Division by zero is excluded). For example:

$$R_T = R_1 + R_2 + R_3 \qquad \text{Solve for } R_2$$

In order to solve for R_2 you must eliminate all of the other terms on the right side of the equal sign. You can see that subtracting R_1 and R_3 from the right side will do the job. Following the rule, you must also subtract the same from the left side. Thus,

$$R_T - R_1 - R_3 = R_1 + R_2 + R_3 - R_1 - R_3$$

and $R_T - R_1 - R_3 = R_2$

If known values are now substituted for R_T, R_1, and R_3 you can determine the value of R_2. Another example is: $X_L = 2\pi FL$ Solve for L. Note that the "L" in the term X_L is a subscript and not the same quantity as L. In this example you will note that if both members of the equation are divided by $2\pi F$, you will obtain $X_L/2\pi F = L$

Another example is:

$X_C = 1/2\pi FC$. Solve for F. Note that the "C" in the term X_C is a subscript and not the same quantity as C. If you multiply both members of the equation by $2\pi C$, you will obtain $2\pi CX_C = 1/F$.

Note that 1 divided by any number or term is the reciprocal of that term. Thus, 1/F is the reciprocal of F. Note also that such operations as finding the reciprocal, finding the square root, and raising to a power may be performed on both members of the equation without changing the equation. To continue the problem, therefore, you can take the reciprocal of both members of the equation. Thus,

$$\frac{1}{2\pi CX_C} = \frac{1}{\frac{1}{F}} \quad \text{and} \quad F = \frac{1}{2\pi CX_C}$$

Transposition:

Transposition is a short-cut means of solving an equation. We have demonstrated that equations could be manipulated by adding, subtracting, multiplying, or dividing both members of the equation by the same quantity without changing the equation. Once you understand the basic operation you will find that transposition provides a short-cut for manipulating equations. For example: Instead of adding a quantity to each member of the equation, you can move (transpose) a term from one side of the equal sign to the other by simply changing the sign. Thus, in $L_T = L_1 + L_2$, you can solve for L_1 simply by moving L_2 to the other side of the equal sign and giving it a (-) sign. $L_T - L_2 = L_1$. Also, if the quantity you are solving for is part of a product, you simply transpose the other quantities of the term to the denominator on the other side of the equal sign. Note that this is the same as dividing both sides of the equation. For example: $E = IR$ and solving for I you have $E/R = I$. Also in $X_L = 2\pi FL$, solving for F you have $X_L/2\pi L = F$.

To solve an equation which requires transposition you should:

1. Observe the equation to be solved or the formula to be used and note the terms containing the unknown.
2. Transpose all of the quantities, other than the unknown, to the other side of the equation. Remember that in transposing you move the quantities by changing the operation, i.e., add if the original equation shows subtraction, multiply if the original equation shows division, and divide when the original equation shows multiplication. Also, if the original equation has the unknown raised to a power, take the root of the remainder of the equation, and if the unknown indicates a root, raise the remainder of the equation to the proper power. For example:

$P = I^2R$ Solve for I

Transposing - $\frac{P}{R} = I^2$

Taking the root - $\sqrt{\frac{P}{R}} = I$

A typical problem which you may be required to solve is:

Given: $E = IR$ Find: P
$P = EI$
$R = 10$
$E = 100$

Step 1: Note that the formula for E contains two known quantities, E and R, and one unknown, I. Also note that the equation for P has one known quantity, E, and two unknown quantities, I and P.

Step 2: In this problem you may solve F = IR for I and then substitute that value in the equation P - EI. Thus,

Solving E = IR for I

$$I = \frac{E}{R} = \frac{100}{10} = 10$$

Substituting the value of I in P = EI,

$$P = EI = 100 \times 10, \qquad P = 1000$$

You may often find it easier to solve problems of this type without two sets of arithmetic calculations. You would accomplish this in the following manner:

Solve E = IR for I = E/R and substitute this expression into the equation P = EI. Thus, $P = E \times E/R = E^2/R$. Now substitute the values and compute P.

$$P = \frac{100 \times 100}{10} = 1000$$

Quadratic Equations:

Often the solution to a problem will result in a quadratic equation, i. e., an equation of the form:

$$ax^2 + bx + c = 0$$

For example:

$$2X^2 - 10X + 12 = 0 \qquad \text{Solve for X}$$

The first step is to factor the algebraic expression. Therefore,

$$(2X - 6)(X-2) = 0$$

If the above expression is true, one of the factors must be equal to zero since the product of two or more factors can be zero only if one of the factors is zero. Therefore,

$$X - 2 = 0 \quad \text{or} \quad 2X - 6 = 0$$
$$X = 2 \qquad\qquad X = 3$$

You will note that the values X = 2 and X = 3 both satisfy the equation, therefore there are two possible solutions to this problem. It can be stated that there will always be two solutions to a quadratic equation. One of the answers may be zero, or imaginary (the square root of a minus number), or one or both answers may be minus. The correct solution for your purpose will depend upon the type of problem. In most of the problems you will solve in fire control, only the positive answers will be of any value.

Assuming the factors of the equation are not apparent, you can solve the equation by use of the quadratic formula:

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

For example: Using the previous equation and recalling the form of the basic quadratic, you will obtain:

$$X = \frac{-(-10) \pm \sqrt{(-10)^2 - 4(2 \cdot 12)}}{2 \cdot 2}$$

$$X = \frac{10 \pm \sqrt{100 - 96}}{4}$$

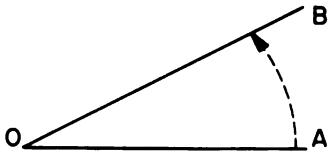
$$X = \frac{10 \pm 2}{4}$$

$$X = \frac{10 + 2}{4} = 3 \quad \text{or} \quad X = \frac{10 - 2}{4} = 2$$

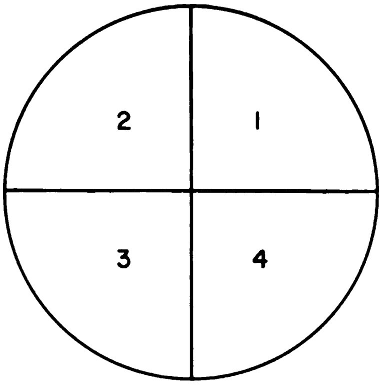
TRIGONOMETRY - This field of mathematics which deals with the relationship between the sides and the angles of a triangle is extremely important in fire control. Trigonometry is required to solve the fire control problem and is also used in solving various electrical and electronic problems.

Because angles are a vital part of trigonometry, a few basic definitions concerning angles will be presented to start the discussion.

An angle is formed whenever two lines meet at a point. To illustrate the generation or construction of various angles, assume the line OA as a reference. Using the end of the line marked O as a pivot, rotate the line to another position OB.



You can see that you effectively have two lines, OA and OB, which meet at point O. Thus, you have an angle AOB. In dealing with angles, they will be most often referred to in terms of degrees. A circle contains 360 degrees (^{o}) and in fire control applications, a degree is further divided into 60 minutes (') and each minute into 60 seconds ("). A circle is also divided into four quadrants as shown below. When the line generating the angle has been rotated counterclockwise (we sill consider this a positive direction) less than 90 degrees, the angle formed will be in the first quadrant. All angles less than 90 degrees are called acute angles. An angle of 90 degrees is called a right angle. If the line is rotated past 90 degrees, it will generate an obtuse angle. An angle of 180 degrees is called a straight angle.

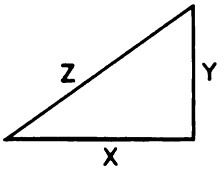


2. QUADRANTS OF A CIRCLE

Any two angles which add up to 90 degrees are called complementary angles. Thus, an angle of 50 degrees is the complement of an angle of 40 degrees. If the sum of any two angles is 180 degrees, the angles are supplementary. Thus, an angle of 80 degrees is the supplement of an angle of 100 degrees.

The whole science of trigonometry is based on the properties of right triangles. Right triangles receive their name from the fact that one angle is a right angle. The properties of right triangles are listed below. These properties are extremely important and must be remembered.

The Pythagorean Theorem:
In any right triangle, the sum of the squares of the sides adjacent to the right angle is equal to the square of the hypotenuse. The hypotenuse is the side opposite the right angle. For example:



$x = 4$
$y = 3$

$z^2 = x^2 + y^2$ and $z = \sqrt{x^2 + y^2}$

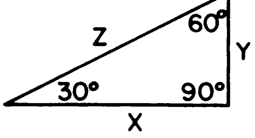
$z = \sqrt{4^2 + 3^2} = \sqrt{25}$

$z = 5$

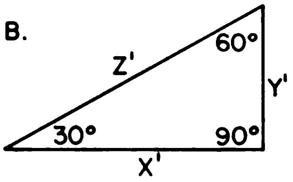
Note that you can transpose and solve for an unknown side if you know one side and the hypotenuse.

Similar Triangles:
When all the angles of one triangle are equal to the angles of another triangle, the two triangles are said to be similar. This applies not only to right triangles but to all triangles. Thus, triangle A is similar to triangle B.

A.



B.

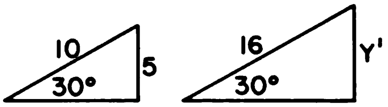


In similar triangles the sides have the relationship:

$$\frac{x}{x'} = \frac{y}{y'} = \frac{z}{z'}$$

The comparison of x/x' or x : x' is called a ratio. A ratio is a comparison of like quantities. For example: 3 miles : 9 miles or 4 days : 5 days. An equation which has ratios as terms is called a proportion. Thus, $\frac{x}{x'} = \frac{y}{y'} = \frac{z}{z'}$ is a proportion.

You can apply the proportional relationship to find unknown sides of a similar triangle. For example:



$$\frac{5}{y'} = \frac{10}{16}$$

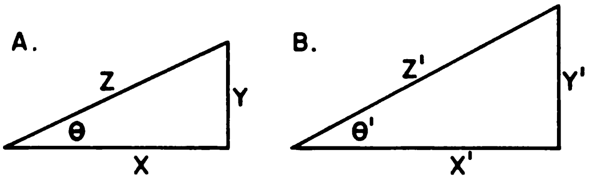
$$10y' = 80$$
$$y' = 8$$

Interior Angles:

The sum of the interior angles of any triangle is 180 degrees. Using this fact, we can prove that two triangles are similar if two angles of one are equal to two angles of the other. The remaining angle in any triangle must be equal to 180° minus the sum of the other two angles.

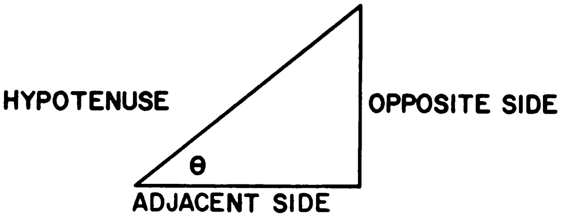
Similar Right Triangles:

Two right triangles are similar if an acute angle of one triangle is equal to an acute angle of the other triangle. Since one angle of a right triangle is 90°, the remaining acute angles must be complementary. Thus, if one angle is designated Θ, the other angle is $(90 - \Theta)$. Most of the uses of trigonometry are based on the fact that two right triangles are similar if one acute angle of one triangle is equal to one acute angle of the other triangle. For example:



With $\Theta = \Theta'$, triangle A is similar to triangle B and $x : x' = y : y' = z : z'$. Note that $x/x' = y/y'$ may be written $x/y = x'/y'$ without changing the relationship. Also $y/z = y'/z'$ and $x/z = x'/z'$. These relationships are the main principle of trigonometry.

Trigonometric Tables: Trigonometric tables are lists of the numerical values of the ratios of sides of right triangles. The various relationships or ratios of the sides are given special names. These trigonometric functions are: sine (sin), cosine (cos), tangent (tan), cosecant (csc), secant (sec), and cotangent (cot). The functions are illustrated in the following example:



$$\sin \Theta = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$$

$$\cos \Theta = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$$

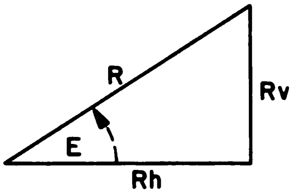
$$\tan \Theta = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$$

$$\csc \Theta = \frac{\text{Hypotenuse}}{\text{Opposite Side}} = \frac{1}{\sin \Theta}$$

$$\sec \Theta = \frac{\text{Hypotenuse}}{\text{Adjacent Side}} = \frac{1}{\cos \Theta}$$

$$\cot \Theta = \frac{\text{Adjacent Side}}{\text{Opposite Side}} = \frac{1}{\tan \Theta}$$

The form of trigonometric tables is varied. Some tables list the values of all six functions and others list only the sine, cosine, and tangent. Also, some tables express the angles in degrees and tenths of degrees and other tables express the angles in degrees and minutes or simply in degrees. The number of decimal places to which the tables are calculated is a matter of required accuracy. Appendix A is a trigonometric table which may be used in this course. The problems which follow will illustrate the use of trigonometry:



$R = 10000$
$E = 30^{\circ}$

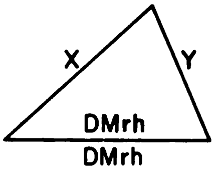
Solve for Rv and Rh:

$\sin E = \frac{Rv}{R}$ and $Rv = R \sin E$

From the "trig" table you find sin 30° is .5 and $Rv = 10000 \times .5 = 5000$

$\cos E = \frac{Rh}{R}$ and $Rh = R \cos E$

From the "trig" table you find cos 30° is .866 and $Rh = 10000 \times .866 = 8660$



$X = 1000$
$Y = 700$

for E and DMrh:

$\tan E = \frac{Y}{X} = \frac{700}{1000} = .7$

From the table you find the angle which has a tangent equal to .7 is 35°, therefore E = 35°.

You can now find DMrh in several ways:

1. $\sin E = \frac{Y}{DMrh}$ and $DMrh = \frac{Y}{\sin E}$

From the table you find sin 35° = .573 and $DMrh = \frac{700}{.573} = 1220$

2. $\cos E = \frac{X}{DMrh}$ and $DMrh = \frac{X}{\cos E}$

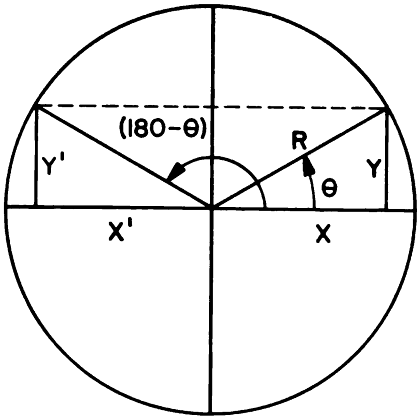
From the table you find cos 35° = .819 and $DMrh = \frac{1000}{.819} = 1220$

3. $DMrh = \sqrt{X^2 + Y^2} = \sqrt{1 \times 10^6 + 4.9 \times 10^5}$

$DMrh = \sqrt{1.49 \times 10^6} = 1.22 \times 10^3$

$DMrh = 1220$

So far in our discussion of the trigonometric functions, we have worked with an acute angle of a right triangle; and thus, all of the angles have been in the first quadrant. It is true, however, that all angles have trigonometric functions and you will often work with angles which are not in the first quadrant. Working with angles greater than 90 degrees will present no problem if you remember a few fundamentals. We will start off by using the sine function to illustrate. You will recall that the sine of an angle is equal to the side opposite divided by the hypotenuse as shown below. You will note that if the circle is a unit circle (R = 1), we will have $\sin \Theta = Y/1 = Y$. Note also that the numerical value of $\sin \Theta$ is equivalent to the projection of Y on the vertical axis (here considered the Y axis).

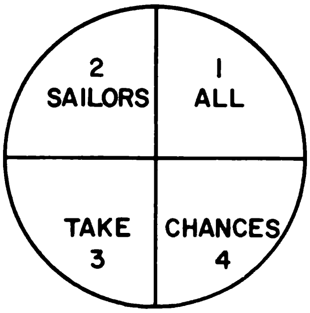


3. CONSTRUCTION OF SINE FUNCTION

Note now the angle constructed in the second quadrant. This angle is equal to $(180 - \Theta)$. You can see that the projection of Y' on the Y axis is the same as the projection of Y and therefore the sine is the same. We can now say that $\sin (180 - \Theta) = \sin \Theta$. For example: sin 150 = sin 30 = .5.

At this point let us review the concept of "direction sense" or sign numbers. With the set of axis shown, values of Y upward (quadrants 1 and 2) are positive and values downward (quadrants 3 and 4) are negative. Also values of X are positive in quadrants 1 and 4 and negative in quadrants 2 and 3.

Now consider again the example, sin (180 - Θ) = sin Θ. You will recall, that since a unit circle was used, the sine of Θ was Y and the sine of (180 - Θ) was Y' and Y = Y'. Now consider the cosine. The cos of Θ = X/1 = X and you can see that the cosine of (180 - Θ) is X' which is equal numerically to X but of opposite sign. Thus, cos (180 - Θ) = - cos Θ. By the same reasoning you will find tan (180 - Θ) = -tan Θ. You can also use the same process to construct angles in the third and fourth quadrants and in doing so the angles in the third quadrant will be (180 + Θ) and angles in the fourth quadrant will be (360 - Θ). The signs of the functions of angles in the various quadrants can be easily remembered by reference to illustration below.



4. SIGNS OF THE FUNCTIONS

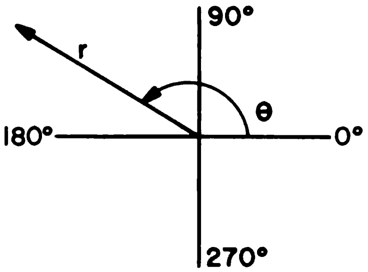
VECTORS - A vector is a line which represents both magnitude and direction of a quantity. In the fire control problem, for example, target motion (Mt) may be represented by a vector whose magnitude is target speed (DMht) and whose direction is target course (Ct).

Vectors may be described in two ways: Polar form and Rectangular form. Note that a line placed over a letter is one way of indicating a vector quantity. For example:

Polar form:	Rectangular form:
$\bar{R} = r \angle\theta$	$\bar{R} = x + y$

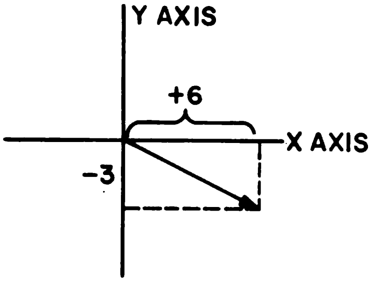
In polar form the magnitude of the vector is (r) and the direction is Θ. For example:

$\bar{R} = 5 \angle 150^{\circ}$



In rectangular form the horizontal and vertical components of the vector are given as x and y. The horizontal component (x) is always listed first. For example:

$\bar{R} = 6 - 3$



You will note that the vector ($\bar{R}$) is the diagonal of the rectangle constructed using x and y.

Vectors expressed in either form may be converted to the other form by use of trigonometry. For example:

$r = \sqrt{x^2 + y^2}$ $\quad$ $\tan\theta = \frac{y}{x}$

$y = r \sin\theta$ $\quad$ $x = r \cos\theta$

Addition and Subtraction of Vectors: Vector problems may be solved either algebraically or graphically. To add or subtract vectors algebraically, the vectors must all be in rectangular form. For example:

$\bar{A} = 10 \angle 60^{\circ}$, $\bar{B} = 6 + 4$, $\bar{C} = -6 \quad -2.66$

$\bar{A} + \bar{B} + \bar{C} = ?$

The first step is to convert $\bar{A}$ to rectangular form. Thus,

$y = r \sin \Theta = (10)\ (.866) = 8.66$

$x = r \cos \Theta = (10)\ (.5) = 5$

Now that the vectors are all in rectangular form, you can add the x components and the y components algebraically.

$$\begin{aligned} \bar{A} &= 5 + 8.66 \\ \bar{B} &= 6 + 4 \\ \bar{C} &= -6 - 2.66 \end{aligned}$$

$A + B + C = 5 + 10$ or $\bar{R} = 5 + 10$

You may now convert to polar form if required.

$r = \sqrt{5^2 + 10^2} = \sqrt{125} = 11.17$

$\tan \Theta = \frac{10}{5} = 2$

From the trig table you find that the angle is approximately 64°. Thus,

$$\bar{R} = 11.17 \angle 64^{\circ}$$

The same problem could have been done graphically. Note that the direction of a vector is indicated by an arrowhead and the end of the vector with the arrowhead is called the head. The other end of the vector is called the tail.

The first step in graphic solution is to lay out the vectors to scale. The vectors are laid out head to tail.

The next step is to construct the resultant by drawing the vector from the tail of the first vector to the head of the last vector. The length of the resultant is the value of r (to scale).

The last step is to measure the angle the resultant makes with the horizontal axis. This angle is Θ. Note that if the resultant is in other than the first quadrant, the required angle is the total angle measured counterclockwise from 0.

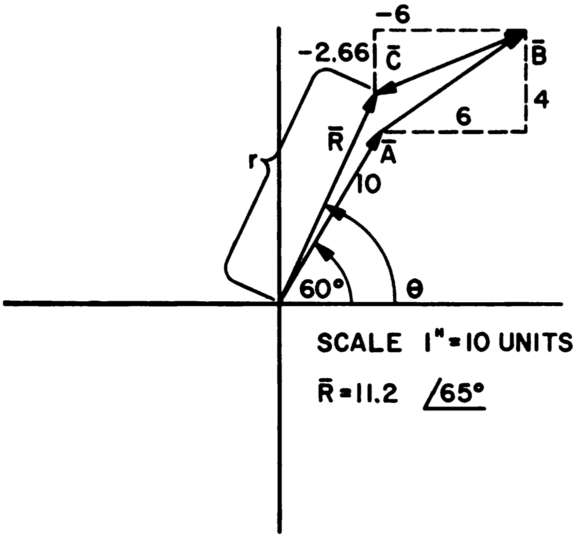
Note also that measuring the projection of the resultant on the x axis will give you the x component and measuring the projection on the y axis will give you the y component. The problem will now be solved graphically.

$\bar{A} = 10 \quad 60^{\circ}$

$\bar{B} = 6 + 4$

$\bar{C} = -6 \quad -2.66$

Note that it is not necessary to convert vector (A) to rectangular form for graphic solution.

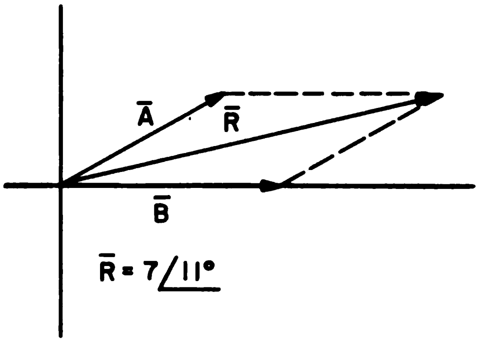


Note that the accuracy of the solution depends on the scale.

In the case of only two vectors, the parallelogram method of graphic solution may be used. The following example will illustrate:

$\bar{A} = 3 \angle 30^\circ$

$\bar{B} = 4 \angle 0^\circ$



STANDARD FIRE CONTROL SYMBOLS

An important step in understanding and solving a fire control problem is the identification of the quantities involved. The symbols used to identify the numerous quantities encountered in fire control, are part of the "language" of an FT. Like any other language, you will become more familiar with it through usage. It is almost an impossible task to memorize all of the variations of the basic quantities. However, if you understand how the basic symbols are modified by symbol modifiers and quantity modifiers, you will be able to interpret new symbols when you encounter them. In comparison to the English language, the basic symbols are the nouns and the symbol modifiers and quantity modifiers are the adjectives. As you proceed with solving the basic fire control problem, you will begin to recognize certain quantities and eventually you will have learned the language.

INTRODUCTION TO OP 1700

OP 1700, "Standard Fire Control Symbols", establishes a system of symbols and definitions for the surface, anti-aircraft, and underwater fire control problems. It includes mathematical quantities associated with the geometrical analysis, and computational and mechanization quantities involved in solving these problems by fire control equipments. Fire control terms, with their accepted definitions, and graphic symbols for mechanical and electrical devices are included. OP 1700 consists of three volumes. Volume 1 contains the symbols for the quantities applicable to solutions of the gun fire control problem. Volume 2 contains the symbols applicable to the underwater problem. Volume 3 contains symbols peculiar to the control of missiles. It is beyond the scope of this trainee's guide to present all of the material contained in OP 1700. However, some of the basic fundamentals and symbols will be presented as background material prior to introducing the fire control problem. In this discussion we will only be concerned with Volume 1.

Volume 1 contains four parts:

1. Symbol system, explaining how symbols are formed, how they are modified to denote special kinds of quantities, and how symbols for new quantities may be constructed.

2. Anti-aircraft related quantities for use in work on specific parts of the gun fire control problem where it is desired to have on hand all values used to express a basic quantity. Special problems arising in the use of symbols are explained here. Separate chapters are used for the steps of the gun fire control problem.

3. Dictionary of symbols for quantities currently in use, or whose future use may be anticipated, arranged alphabetically.

4. Appendices of letters with their meanings when used as basic symbols, basic symbol modifiers, and quantity modifiers, arranged alphabetically.

Scope of the Symbol System - The quantities and geometrical elements symbolized are those necessary to express the following five steps in solving the general fire control problem:

1. Determination of present target position with respect to own ship, expressed in various coordinates, and considering parallax effects.

2. Determination of linear and angular movements and directions of movement between own ship and target, referred to various frames of reference, and considering parallax effects.

3. Expression of wind quantities.

4. Expression of linear and angular offsets resulting from ballistics and prediction.

5. Expression of orders positioning the gun along the line of fire, considering parallax effects.

The computational quantities symbolized are those necessary to express:

1. Portions of, and additions and corrections to geometrical quantities, such as deck tilt correction, increments, etc.

2. Methods by which geometrical quantities are obtained, such as computed, designated, estimated, etc.

Mechanization quantities symbolized are those which are associated with geometrical quantities, although they may not be directly connected with them, for example, rate control quantities.

Any system of measurement must have a reference. In Naval gun fire control, reference frames originate on own ship. Before we continue the discussion of symbols, it is necessary to define some of the planes and lines used as references in fire control.

Horizontal Plane - The plane tangent to the earth's surface at the location of the ship.

Deck Plane - The plane coincident with or parallel to the ship's deck.

Vertical Plane - A plane perpendicular to the horizontal plane and intersecting it at any designated point.

Normal Plane - A plane perpendicular to the deck plane and intersecting it at any designated point.

Slant Plane - A plane which intersects either the horizontal or deck plane at some discrete angle whose value is determined by the elevation angle of the line-of-sight.

Line-of-Sight (LOS) - A line from a point on the ship to a target.

Line-of-Fire (LOF) - The line along which a weapon is fired to hit the target.

Now that the basic references have been defined, we will proceed with our discussion of symbols.

SYMBOLS AND MODIFIERS - OP 1700, Volume 1, Appendices A, B, and C, list the Basic Symbols, Basic Symbol Modifiers, and Quantity Modifiers. These appendices are included in this Trainee's Guide for your reference.

The basic symbols (Appendix A) represent the basic geometrical quantity in each class.

The basic symbol modifiers (Appendix B) are used to modify the basic symbols to show the reference of the quantity.

The quantity modifiers (Appendix C) are used to indicate portions of the various quantities, frame of measurement of rates, etc. Anytime a quantity modifier is used, the basic quantity will be enclosed in parentheses. The meaning of the quantity modifier depends on whether the modifier is placed in front of, or following, the parenthesis.

BASIC SYMBOLS (APPENDIX A, OP 1700) - The format that will be used to list the basic symbols is: The symbol will be listed first, the name second, and the meaning when used alone will be listed last.

A - Angular movement in elevation - The difference in elevation from the horizontal plane between the present line of sight and the line to the future target position, measured upward to the line to the future target position in a vertical plane.

B Bearing - The relative bearing of the target measured from the vertical plane through own ship centerline to the vertical plane through the line of sight in the horizontal plane clockwise from own ship centerline.

C - Course - The course of the target from the north-south vertical plane to the vertical plane through the relative target speed vector in the frame used by the fire control system, measured in the horizontal plane clockwise from north.

D - Rate of - The differentiating operator d/dt.

E - Elevation - The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight.

Ei - Level - The angle between the horizontal plane and the deck plane, measured downward from the horizontal plane (on the target side of own ship) in the vertical plane through the line of sight.

F -
G -
H -

I - Angle of inclination - Only useful as a rate. DI expresses the rate of rotation of own ship with respect to the earth frame.

J - Jump deviation - No meaning.

K -

L - Sight deflection - The total lead angle between the line of sight and the line of fire.

M - Linear movement - The total linear displacement during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.

N -
O -

P - Gun parallax base length - The total linear displacement between the reference point and the gun measured along the gun parallax base line.

Ps - Director parallax base length - The total linear displacement between the reference point and the director measured along the director parallax base line.

Q -

R - Range - The distance between own ship and target measured along the line of sight.

S - Lateral angular movement - The total angular displacement measured from the line of sight to the line to the future target position.

T - Time - Elapsed time.

U - Velocity - The initial velocity of the projectile with respect to the gun muzzles at the instant the projectile leaves the gun.

V - Sight angle - The difference in elevation between the line of sight and the line of fire measured in a vertical plane.

W - Wind rate - The total rate of the true wind measured with respect to the earth.

X -
Y -

Z - Cross level - Angle between the vertical plane through the line of sight, and the normal plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight and the horizontal plane.

BASIC SYMBOL MODIFIERS (APPENDIX B, OP 1700) - The format that will be used to list the symbol modifiers is: The modifier will be listed first, the name second, and what it is used to indicate will be listed last.

a - Apparent - Quantities expressing rates and angles of apparent wind.

b - Bearing - Quantities in direction affecting bearing.

c -

d - Deck - Quantities measured in, from, or about axes in the deck.

e - Elevation - Quantities in direction affecting elevation.

f -

g - Gun - Quantities measured from, to, or about line of fire or gun.

h - Horizontal - Quantities measured in horizontal plane.

i -
j -

k - Earth - Quantities expressing earth rates.

l -
m -
n -

o - Own ship - Quantities measured from, to, or about own ship centerline, and quantities expressing own ship rates and own ship wind rates.

p - Prediction.

q - Heading - The compass head of own ship or target.

r - Range - Quantities in direction affecting range.

s - Line of sight - Quantities measured from, to, or about line of sight or director.

t - Target - Quantities measured from, to, or about target centerline, and quantities expressing target rates.

u -

v - Vertical - Quantities in vertical direction.

w - Wind - Quantities related to wind.

x - East-West - Quantities measured in east-west direction.

y - North-South - Quantities measured from north or in north-south direction.

z - Cross level - Quantities related to cross roll.

' - Prime (before quantity) - Measurement from a normal plane.

' - Prime (after quantity) - Measurement to or in a normal plane.

" - Double prime (before quantity) - Measurement from a plane normal to the slant plane.

" - Double prime (after quantity) - Measurement to or in a plane normal to the slant plane.

1 - Present position - Quantities measured with respect to present target position.

2 - Future position - Quantities measured with respect to future target position.

3 - Advance position - Quantities measured with respect to advance position.

4 - Aiming position - Quantities measured with respect to aiming position.

5 - Fuze - Quantities used in fuze computations.

QUANTITY MODIFIERS (APPENDIX C, OP 1700) - You will remember that these modifiers are used only when the basic quantity is enclosed in parentheses. The format that will be used to list the quantity modifiers is: The modifier will be listed first, the name second, the meaning when used before the parentheses will be listed third, and the meaning when used after the parentheses will be listed last.

a - Advance - The portion of the quantity measured to the advance position. No meaning when used after parentheses.

b - Ballistics - The portion of the quantity accounting for superelevation or drift. The quantity corrected for the effect of superelevation or drift.

c - Computed or generated - The value of a quantity as computed or generated in the mechanism. No meaning when used after parentheses.

d - Designated - The designated value of the quantity. No meaning when used after parentheses.

e - Estimated or error - The estimated value of the quantity or the error in that quantity (error meaning used only with initial velocity). No meaning when used after parentheses.

f - Function - A function of the quantity. No meaning when used after parentheses.

g - Dead time - The correction to the quantity due to dead time. The quantity corrected for the effect of dead time.

h -

i - Increment - An increment of the quantity. No meaning when used after parentheses.

j - Computational addition or partial - A computational addition to the quantity. A partial value of the quantity.

k - Earth - No meaning when used before parentheses. The quantity referred to the earth frame.

l - Initial - The initial value of the quantity. No meaning when used after parentheses.

m - Relative motion - The portion of that quantity accounting for relative motion between own ship and target. The quantity corrected for the effect of relative motion between own ship and target.

n -

o - Observed or measured - The observed or measured value of the quantity. Referred to a frame rigidly attached to own ship.

p - Gun parallax - The portion of the quantity accounting for gun parallax. The quantity corrected for the effect of gun parallax.

ps - Director parallax - The portion of the quantity accounting for director parallax. The quantity corrected for the effect of director parallax.

q - Corrective input or spot - A corrective input or spot to the quantity. No meaning when used after parentheses.

r - Rate control - The rate control correction to a quantity. The quantity including the rate control correction.

s - Selected - A selected value of the quantity. Referred to the inertial frame.

u - Initial velocity loss - The portion fo the quantity accounting for change in initial velocity. The change corrected for change in initial velocity.

v -

w - Wind - The portion of the quantity accounting for the effect of the wind. The quantity corrected for the effect of the wind.

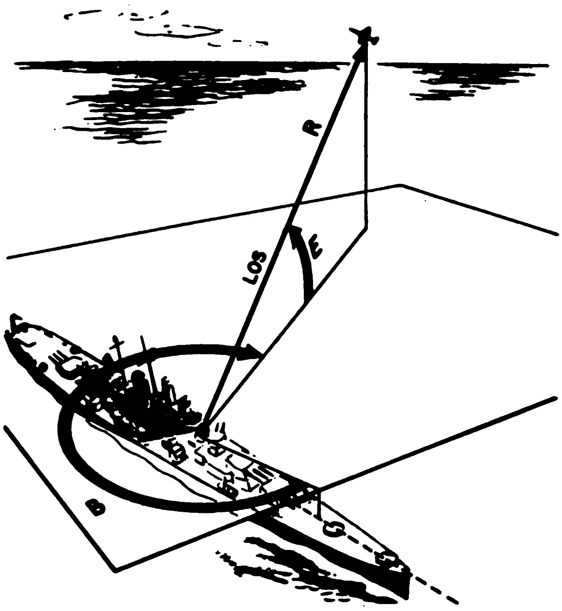
x -
y -
z -

You have been introduced to the basic symbols and their modifiers. As an aid in learning the "language", you should refer to Appendices A, B, and C of OP 1700 each time you encounter a new combination of symbols and modifiers. After you have determined what the quantity represents, you should refer to the Dictionary of Symbols section of OP 1700 for a complete description of the quantity and the accepted nomenclature.

COORDINATE SYSTEMS - Systems of coordinates used for measurement of fire control quantities are: Spherical, Cylindrical, and Cartesian.

Measurement in spherical coordinates is shown below. Target position is defined in terms of:

1. Bearing angle (B)
2. Elevation angle (E)
3. Range along line of sight (R)

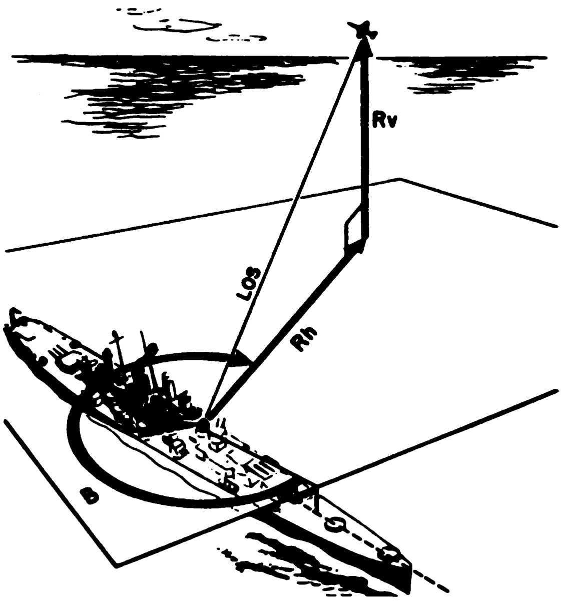


5. TARGET POSITION IN SPHERICAL COORDINATES

Refer to Basic Symbols to see which planes are used as references for the measurement of bearing and elevation angles. Now suppose you wish to indicate the bearing angle with respect to true north. Referring to Basic Symbol Modifiers, you will find "y", when used as a symbol modifier, means measured from north. The bearing angle would now be symbolized "By". Suppose now that the ship is pitching and rolling so that the horizontal plane is not the same as the deck plane. If no means of stabilization is used in measuring the angle, the elevation angle will no longer be referenced to the horizontal plane. Referring to Basic Symbol Modifiers, you will find "d" indicates measurement with respect to the deck plane. The elevation angle is now symbolized "Ed".

Measurement in cylindrical coordinates is shown below. Target position is defined in terms of:

1. Bearing angle (B)
2. Vertical range component (Rv)
   This is target height.
3. Horizontal range component (Rh)

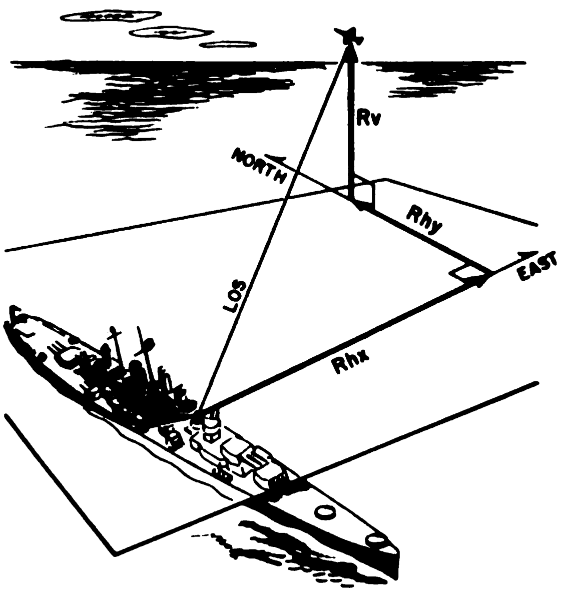


6. TARGET POSITION IN CYLINDRICAL COORDINATES

Refer to the lists of symbols and modifiers and determine the meaning of: Rd, Rvd, and Rv'.

Measurement in cartesian coordinates is shown below. Target position is defined in terms of:

1. Vertical range component (Rv)
2. Horizontal range component in N-S direction (Rhy)
3. Horizontal range component in E-W direction (Rhx)



7. TARGET POSITION IN CARTESIAN COORDINATES

You have been introduced to the various symbols and modifiers which are used to denote various quantities in fire control. You are now going to study some of the factors which affect the fire control problem.

There are many variations or forms of the basic problem. The problems presented by targets on the surface of the sea, targets under the sea, or targets in the air, are all slightly different. However, the basic problem remains the same; how can a ship either underway or dead in the water, destroy a stationary or moving target.

Most of the forces, controllable and uncontrollable, that affect the flight of a gun projectile also affect the flight of guided missiles. You will therefore appreciate the appropriateness of the introduction of ballistics as a background subject to the study of fire control.

The term "Ballistics" was derived from "Ballisto" which was the name applied to an ancient weapon used for hurling large stones or other missiles against fortifications. Ballistics, as the term is now used, is the study of the motion of a projectile from the time the propelling charge is ignited until the time the projectile reaches the target. The study of ballistics is normally divided into two classifications: Interior and Exterior. Interior ballistics is primarily concerned with the movement of projectiles inside the gun barrel, while exterior ballistics is concerned with motion of a projectile after leaving the gun.

INTERIOR BALLISTICS

One of the most important factors of interior ballistics affecting a projectile's I. V. (Initial Velocity) is the rate at which the propelling charge burns. All naval guns use propelling charges consisting of cylindrical grains, perforated from end to end with one or more holes. This type charge results in the least muzzle loss (explosive energy wasted after the projectile leaves the muzzle) and highest muzzle (initial) velocity for a given charge.

Larger, solid powder grains burn slowest, resulting in the greatest muzzle loss and subsequent lowest I. V. The most efficient are the small, perforated grains which are the fastest burning of the low explosives. Thus, you can see that the highest muzzle velocity is obtained by using small perforated grains.

The temperature of the propelling charge also has a very definite effect on projectile I. V. A typical 5-inch gun may have a normal I. V. of 2600 fps (feet per second) at a powder temperature of 90 degrees Fahrenheit. A temperature drop of 60 degrees from normal may decrease the I. V. as much as 90 fps.

Another factor which affects I. V. is erosion. Erosion is the wearing away of the gun bore during firing. Your first guess would probably be that erosion is caused by the friction produced by the rubbing of the rotating band against the bore as the projectile travels through the gun, but surprisingly this is not true. Some of the causes of erosion are:

1. The surface of the bore becomes intensely heated during firing and the hot gases rushing across the hot metal scour the surface, as would steel wool.

2. The rapid heating and cooling of the bore during and between rounds tends to weaken the metal, and small surface cracks may develop.

3. Hot gases escaping around the rotating band of the projectile during firing act as high velocity jets, causing additional scouring and cutting of the bore's surface.

Erosion of the gun bore occurs mainly at the origin of rifling, the point in the gun bore near the breech where the rifling begins. In guns using bag ammunition, the projectile may be rammed further into the gun as a result of the erosion. This will result in reduced density of loading, and hence the muzzle velocity is decreased.

Erosion also causes the tops of the lands of the rifled bore to wear away faster than the bottoms of the grooves, which increases the amount of gas which escapes past the rotating band. This further reduces the pressure behind the projectile and thus decreases the muzzle velocity.

You have seen that erosion of the gun bore is due primarily to the high temperature and velocity of the expanding gases during firing, and the alternate heating and cooling of the gun barrel. The longer the hot gases remain in the gun, the greater the erosion; the more time allowed to elapse between rounds, the more the barrel cools, thus increasing wear due to change in temperature. Thus larger guns with their longer barrels suffer more from erosion on each round fired than do small guns.

Even a slight amount of erosion reduces the muzzle velocity and hence reduces the range and accuracy of the gun. The gun eventually becomes unserviceable when erosion reduces its effectiveness to a point where the projectiles fired no longer hit the target. Before a gun becomes inaccurate due to erosion, the barrel must be replaced or relined (in guns equipped with removable barrel liner). The life of a big gun is less in terms of rounds fired than that of a machine gun. A record is kept of the number of rounds fired by each gun so that proper information on bore erosion can be supplied for fire control purposes, and to enable the weapons officer to know when the barrel needs replacing.

You have been introduced to the factors which affect the projectile during its travel through the gun bore. You should understand that these are the controllable forces that affect a projectile; that is, the forces whose effect can actually be predetermined and the necessary corrections introduced into a computer to compensate for that effect.

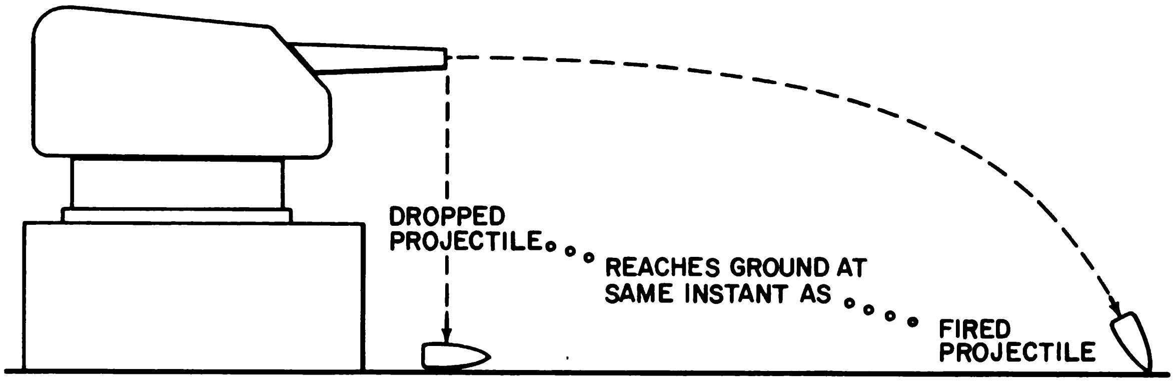
At the instant the projectile leaves the gun, its initial velocity and direction are fixed and the influence of the interior ballistics of the weapon is ended. The course which the projectile follows after leaving the gun muzzle is determined by exterior ballistics. Thus, interior and exterior ballistics are related by projectile initial velocity and direction.

EXTERIOR BALLISTICS

Exterior ballistics involves an analysis of the forces which act on the projectile and affect its course during flight from gun muzzle to target. Exterior ballistics is also concerned with the practical problem of laying a weapon (setting it in elevation and train) to incorporate ballistic corrections and enable a projectile fired from it to hit the target.

If there were no forces acting on a projectile during its flight to the target, fire control would be a simple matter. All that would be necessary to score a hit on a fixed target from a fixed position would be to aim the gun directly at the target and fire.

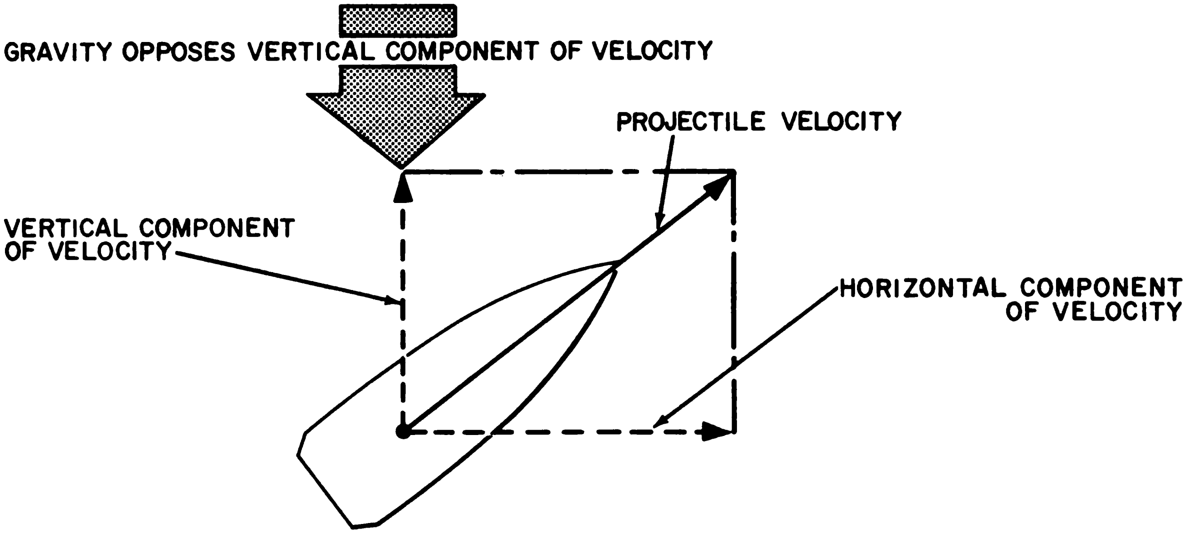
When a projectile is fired from a gun, its momentum, resulting from the projectile I. V., tries to keep it on a course in line with the gun bore. However, many forces act on



8. EFFECTS OF GRAVITY ON PROJECTILES IN A VACUUM

the projectile before it reaches the target. The earth's gravity pulls it down; air resistance, due to the friction of the projectile pushing through the air; slows it down; wind and air currents force the projectile off its original course; and the spinning of the projectile tends to make it drift off course. All of these factors greatly alter the projectile's course and must be considered in determing how to elevate and train the weapon in order to hit the target.

EFFECTS OF GRAVITY - If it were possible to remove all of the air from around the gun and target; the only force which would act on a projectile fired into the resulting vacuum would be the downward pull of gravity. As shown in the illustration above, if the gun was aimed perfectly horizontal and a projectile was dropped vertically from the level of the gun muzzle; both projectiles would hit the ground at exactly the same instant. This illustrates that the force exerted on a projectile by gravity is always the same for a given projectile, regardless of its speed or direction of travel. Referring to the illustration below, you can see that if the weapon was pointed up at some angle and a projectile fired, its initial velocity could be resolved into horizontal and vertical components. There is no opposition offered, in a vacuum, to the horizontal velocity component. Therefore, this velocity remains constant during the projectile's flight. Gravity, however,



9. HOW GRAVITY OPPOSES UPWARD TRAVEL OF PROJECTILE

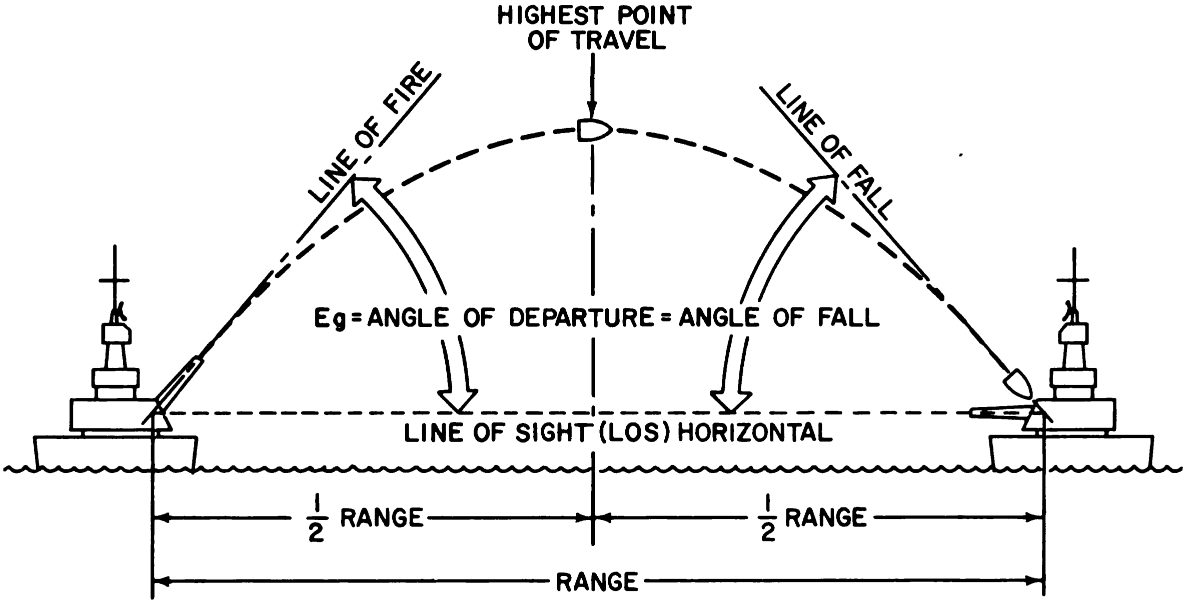
exerts a constant downward force which opposes the vertical velocity component. As the projectile continues its flight from gun to target, gravity continues to oppose and reduce the vertical velocity of the projectile until it becomes zero at the midpoint of the flight. From this point onward, gravity causes the projectile to attain a downward vertical velocity which continues to increase until the projectile hits the target. Thus, the force exerted on the projectile by gravity causes it to follow a curved path from the gun to the target. This path is called the projectile's trajectory.

At the midpoint of the trajectory, gravity has acted on the projectile for a time sufficient to reduce the vertical velocity to zero. The time required for the projectile to travel from the trajectory midpoint to the target is the same as is required to reach the midpoint from the gun. Therefore, since the force exerted by gravity is constant, the downward velocity attained by the projectile by the time it reaches the target (surface target) will equal the vertical component of the I. V. The total velocity of the projectile when it hits the target will equal the I. V. since the horizontal component has not changed during the flight of the projectile.

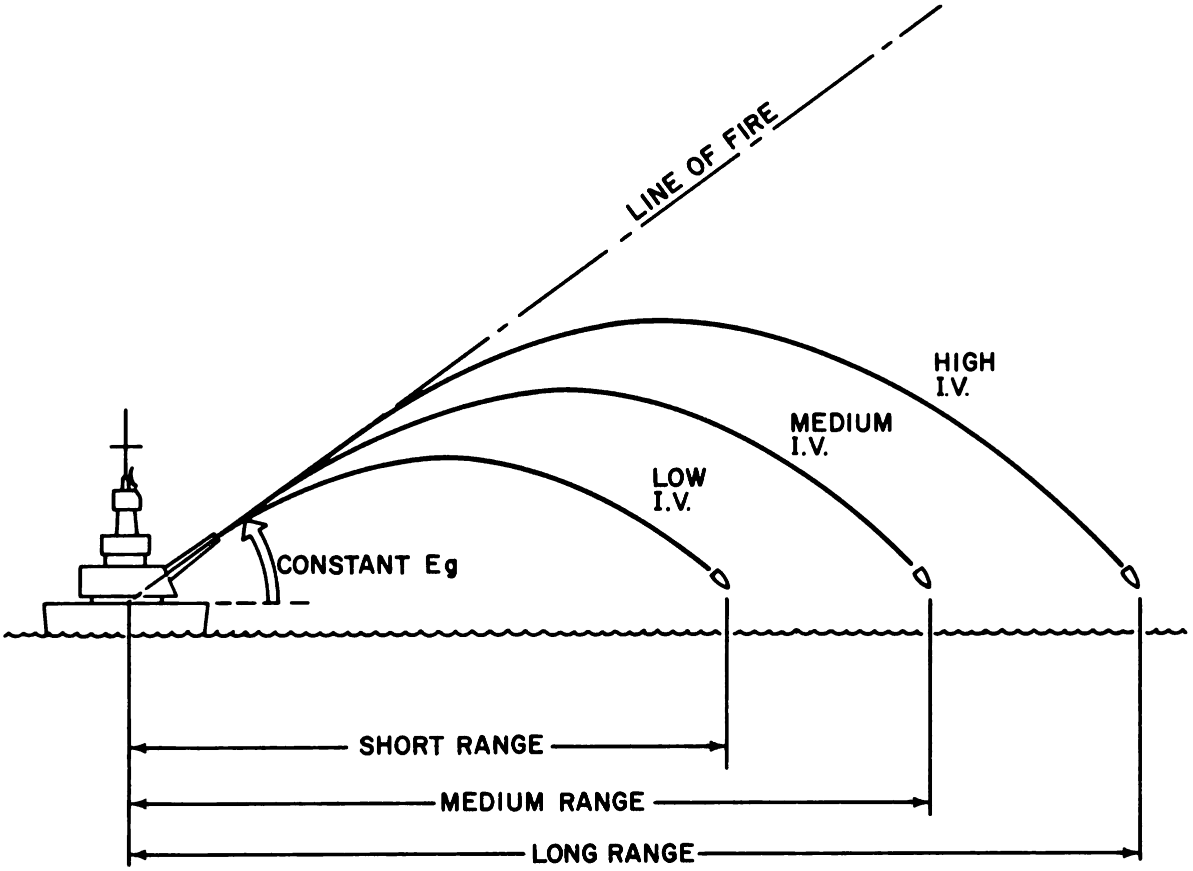
As shown below, the trajectory of a projectile fired in a vacuum would have a regular curve with the highest point of travel at a point midway between the gun and the target.

The projectile leaves the gun along the line of departure and approaches the target along the line of fall. These lines make equal angles with the horizontal, therefore, the angle of departure (gun elevation angle, Eg) equals the angle of fall. In the case illustrated, when the gun and target are at the same level, the line of sight (L. O. S.) from the gun to the target is horizontal.

Of course it is not possible to create a vacuum between the gun and the target; but if you understand the vacuum trajectory, it will be easier for you to understand the effects on projectile trajectory of air resistance, wind, and projectile spin. The effect of gravity on a projectile's course of flight is constant in a vacuum or in air. If the effect of gravity was the only factor to consider, fire control would still be a simple problem. It is primarily the other exterior ballistics factors which require elaborate consideration before the fire control problem can be solved.



10. CHARACTERISTICS OF A VACUUM TRAJECTORY



11. EFFECT OF I. V. ON RANGE FOR CONSTANT ELEVATION ANGLE, VACUUM TRAJECTORY

The initial velocity and direction of a projectile determine where it will fall. These are the only properties which can be imparted to a projectile by a weapon and if they could not be controlled, the gunner would have no control of his weapons. Once the projectile has left the weapon, the gunner cannot tell it where to go. (You will realize that we are talking primarily of gun projectiles. In the case of guided missiles, they can be told where to go.) It is vitally important that we know exactly how a projectile will travel after it leaves the gun at a known speed and in a known direction, so that we can adjust these factors as necessary to make the projectile hit the target.

The illustration above shows the effect of initial velocity on range. If a projectile is fired in a vacuum, at a fixed elevation angle, and the I. V. is varied; the range will increase as the I. V. is increased. Since the vertical component of velocity is larger, it takes longer for the constant force of gravity to overcome the projectile's upward travel. This allows the horizontal velocity component to carry the projectile farther from the gun, resulting in an increase of range.

In guns using bag ammunition, it is possible to change I. V. by using larger or smaller propelling charges. Certain semi-fixed ammunition intended for shore bombardment uses special low I. V. powder for the propelling charge. However, no control of range is possible by varying I. V. for guns using fixed ammunition since the I. V. of such guns is fixed for a certain gun using given ammunition. (Possible variations of powder temperature from the standard of 90 degrees Fahrenheit are not considered.)

If a projectile is fired in a vacuum, with a fixed I. V., its range will depend only on gun elevation angle. Gun elevation angle, Eg, is the angle between the gun bore and the horizontal. As Eg is increased from 0 to 45 degrees, the range increases since it takes longer for gravity to overcome the projectile's vertical velocity, and during this time the projectile travels farther from the gun. Maximum range in a vacuum would be at Eg = 45 degrees.

As the vertical velocity increases due to increased elevation, the horizontal velocity decreases. As the gun is elevated higher than 45 degrees, the time the projectile is traveling continues to increase; but the horizontal velocity will be so reduced, that even in the longer time, the projectile will not go as far.

You can see that for any given range there are two possible elevation angles - one less than 45 degrees and one greater than 45 degrees. To keep the time of flight to a minimum, elevations less than 45 degrees are used for fire against surface targets. Elevations greater than 45 degrees are ordinarily used only for antiaircraft fire.

So far we have considered the flight of a projectile in a vacuum and you have seen how gravity, initial velocity, and elevation affect the projectile's trajectory when air resistance is neglected. We cannot create a vacuum in the combat area, therefore, we must determine, understand, and compensate for the effects of air resistance on the projectile's course if we are going to score a hit on the target.

The effect of gravity on a projectile is constant, regardless of whether the projectile travels in air or in a vacuum. Gun elevation and I. V. still affect the trajectory in the same manner; hence, the preceding discussion of these effects in a vacuum also applies to the flight of a projectile in air.

EFFECTS OF AIR RESISTANCE - As a projectile travels through air, the air is forced out of the projectile's path just as a ship forces water from in front of it as it moves through the water. As the air is moved aside, it exerts an opposing force on the projectile.

Just as the force of gravity opposes the vertical component of projectile velocity, the force due to air resistance always acts in opposition to the total velocity of the projectile. You will remember that the total velocity of the projectile is the vector sum of the vertical and horizontal components.

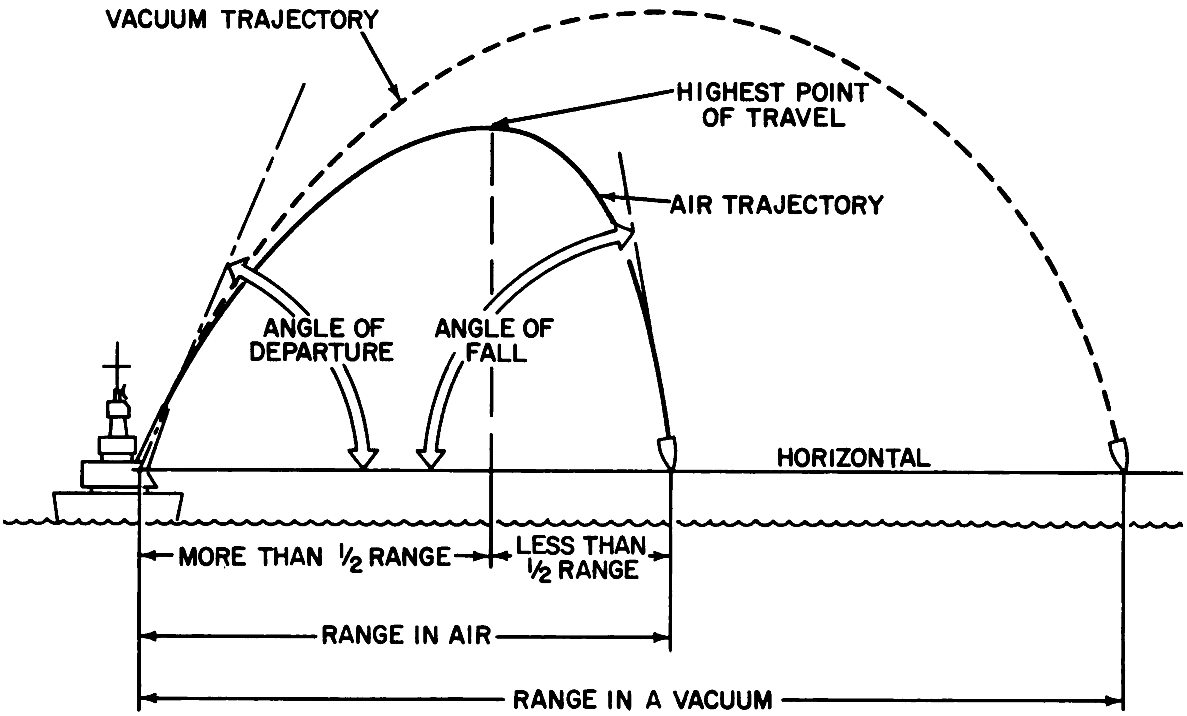
Air resistance varies depending on projectile size and velocity. The faster a projectile moves through the air, the faster it must force the air out of its path. The more rapidly the air is moved out of its original position, the greater the force it exerts on the projectile. Thus, air resistance has a greater effect on projectiles traveling at high velocities than it does on slow-moving projectiles.

As long as a projectile is in flight, air resistance continues to reduce its velocity. Thus, the projectile travels much more slowly as it approaches the target than it did when it left the gun muzzle. Also, the longer a projectile remains in flight, the more slowly it travels. As seen in the illustration below, this results in a shortening of the trajectory at the far end and a great reduction in range. The trajectory high point is no longer at the midpoint as it was in a vacuum, but will be nearer the point of impact than it is to the gun. The angle of fall is greater than the angle of departure and the striking velocity (projectile velocity when it hits the target) is less than the initial velocity.

Any projectile fired in a vacuum at an elevation of 40 degrees and with an I. V. of 2500 fps will attain a horizontal range of 192, 000 yards (almost 100 miles). When fired in air, at an elevation of 40 degrees, a 5-inch projectile has a range of 17, 000 yards and a 3-inch projectile has a range of 14, 000 yards.

Because of air resistance, maximum projectile range is not attained when the elevation angle is 45 degrees as is true in a vacuum. In air, maximum range occurs when the elevation angle is slightly more or less than 45 degrees. The angle for maximum range depends on the characteristics of the gun and the projectile. For example: The maximum range for a 5-inch gun is obtained when Eg = 44 degrees, 35 minutes.

You can see that the presence of air greatly complicates the fire control problem, and that careful adjustments are required to compensate for its effects.



12. VACUUM AND AIR TRAJECTORIES COMPARED

EFFECTS OF DRIFT - Due to the rifling of the bore, every projectile fired by a naval gun drifts off to the right as it travels through the air. The amount that a projectile will drift increases with range; however, do not confuse this drift due to rifling of the gun bore with the drift caused by the wind's effect on a projectile.

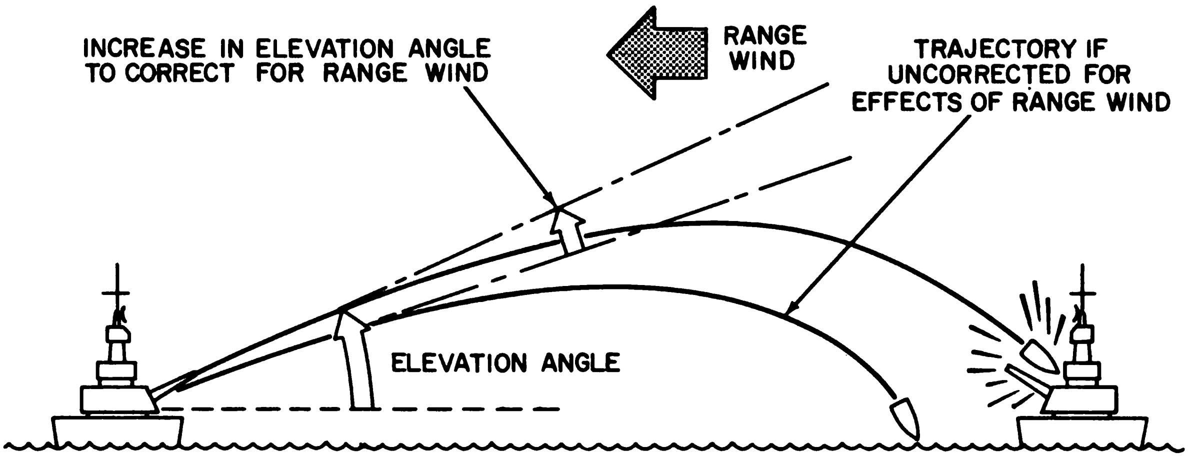
The reason that naval guns are always rifled is: The gyroscopic action of the spinning projectile keeps it pointing almost exactly along its trajectory. This prevents the projectile from tumbling and weaving around its flight path; it also insures its landing nose first.

As you can see, the rifling of the gun barrel produced a good effect but it also resulted in the harmful effect of causing a projectile to always drift to the right of its intended target. The amount that various projectiles will drift has been determined by experiments and the data has been tabulated for reference. Computers are designed to include the necessary correction to compensate for the effect of drift.

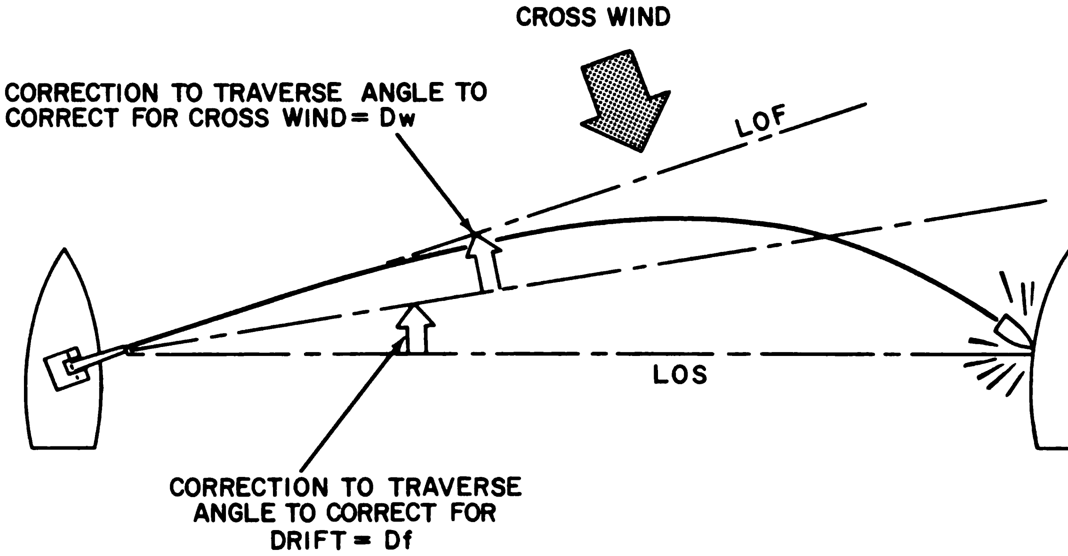
EFFECTS OF WIND - If you have ever played football on a windy day, you are familiar with the effects of wind on an object in flight. Depending on the direction and velocity of the wind, your well-aimed forward pass may have curved to the right or left, or fallen short of or beyond the point where you wanted it to land. Wind has exactly the same effect on a projectile in flight. If the wind blows from the left, the projectile will turn to the right and vice versa. If the projectile is headed into the wind, its range will be decreased; and if it travels with the wind, its range will be increased. You can see that the effects of wind must be considered in the solution of the fire control problem.

When the projectile is first fired, it is traveling at such high speed that the wind has very little effect. As the projectile slows down during its flight, the wind affects the projectile's course more and more. Hence, the longer a projectile remains in flight, the greater the effect of the wind and thus, wind deflection increases with range.

Two other factors which affect the amount the projectile deflects are: Wind speed and projectile size. Obviously the greater the wind velocity, the greater its effect on the projectile. Also, as was true for deflection due to drift, large projectiles have more initial momentum (weight times velocity) and can therefore resist the effects of wind better than small projectiles.


INCREASE IN ELEVATION ANGLE TO CORRECT FOR RANGE WIND
RANGE WIND
TRAJECTORY IF UNCORRECTED FOR EFFECTS OF RANGE WIND
ELEVATION ANGLE

CORRECTING FOR THE EFFECTS OF RANGE WIND

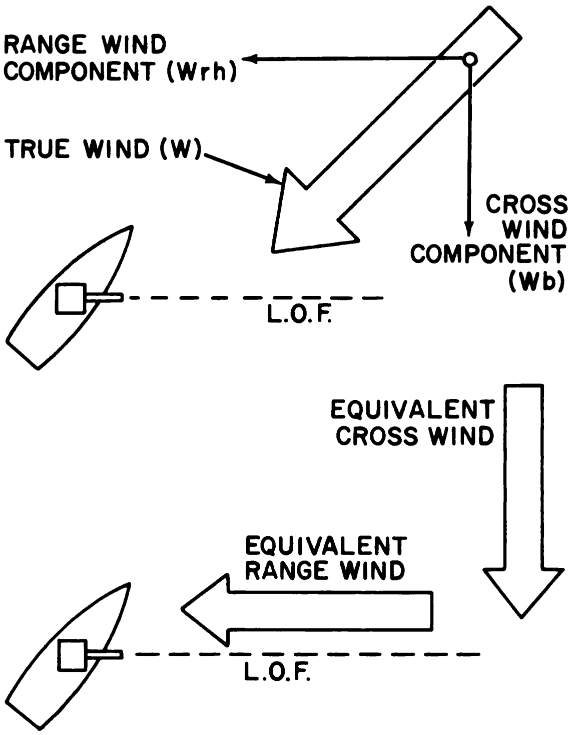

CROSS WIND
CORRECTION TO TRAVERSE ANGLE TO CORRECT FOR CROSS WIND= Dw
LOF
LOS
CORRECTION TO TRAVERSE ANGLE TO CORRECT FOR DRIFT = Df

CORRECTING FOR THE EFFECTS OF CROSS WIND

13. CORRECTIONS FOR THE EFFECTS OF WIND

Refer to the illustration above. If the wind is blowing along the line of fire, either with or against the projectile, it is called range wind. If the wind is blowing at right angles to the line of fire, it is called cross wind. Range wind is compensated for by increasing or decreasing gun elevation angle. Corrections for cross wind are made to the train angle separately from corrections for drift.

If the wind always blew in line with, or at right angles to the line of fire (L. O. F.), it would be a relatively simple matter to compute the corrections required when wind velocity was known. Usually, however, the wind blows at some angle to the line of fire. In order to correct for range and cross winds, it is necessary to resolve the true wind into components in line with, and perpendicular to the L. O. F. as shown in the illustration below. When this is done, each component can be treated individually and the proper gun setting adjustments made.



14. READING TRUE WIND

Corrections for the effects of wind are only approximate because wind speed and direction are usually different at various altitudes. For instance, the wind might be blowing from the north on the surface, and from the south at an altitude of 6000 feet. In such a case, the projectile will be affected differently at various levels of flight.

Wind conditions at different altitudes are determined by observations from an airplane or by observing the movements of a small balloon. If it is found that the projectile's trajectory will take it through winds which move in opposite directions, a "weighted ballistic wind" must be used to compute gun setting corrections. This ballistic wind makes allowance for variations in wind velocity and direction and for variations in air density at different altitudes. In solving the fire control problem, weighted ballistic wind is the most effective true wind.

Another factor which must be considered is own ship's wind. You can visualize that as the ship moves, it creates a wind across the deck. This wind is called own ship's wind. Just as own ship's speed is combined with projectile I. V., own ship's wind must be combined with true wind. The resultant, called apparent wind, is used in the solution of the fire control problem.

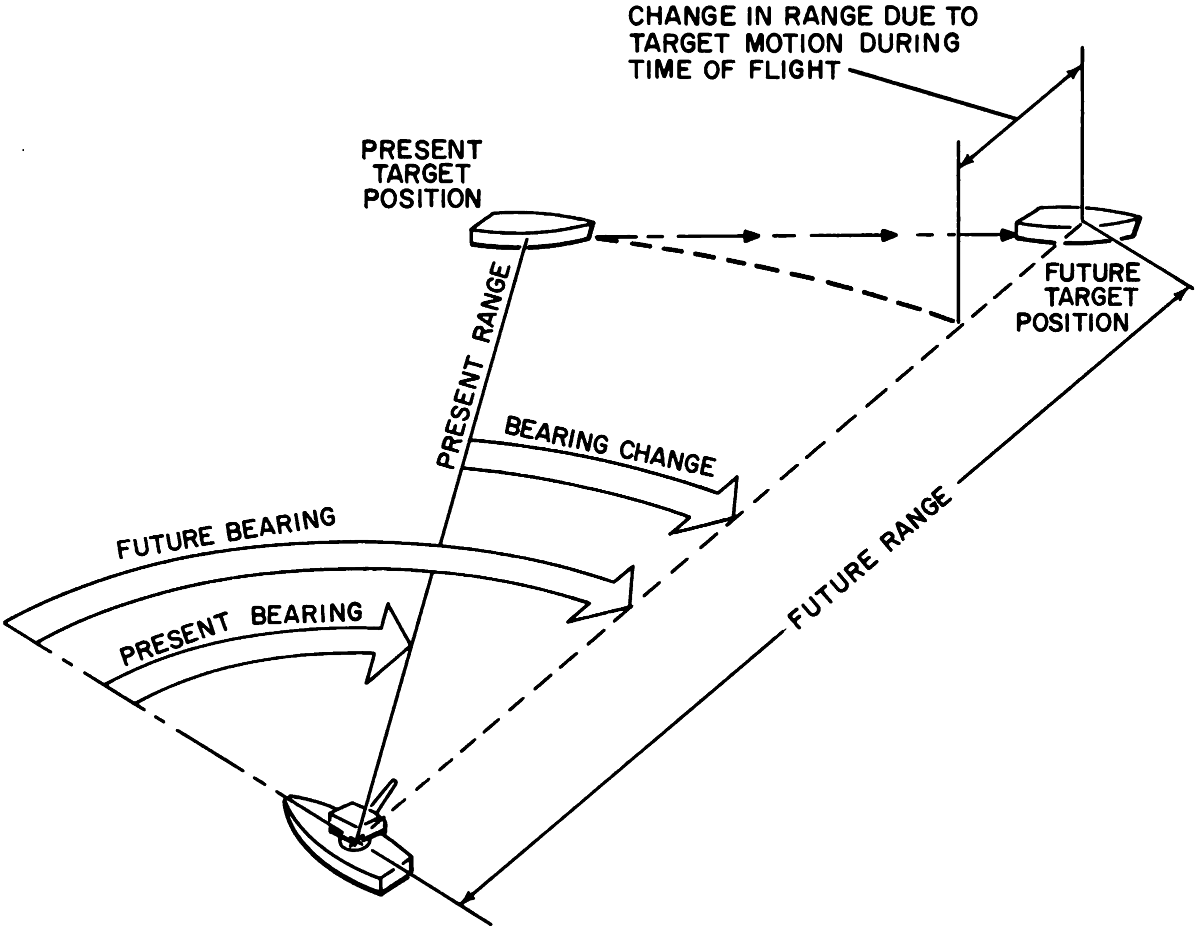
EFFECTS OF RELATIVE MOTION - Now you are ready to go on and apply the things you have already learned to the study of hitting a moving target from a moving ship. All of the principles of interior and exterior ballistics that apply to a stationary target and gun also hold true when both own ship and target in motion.

When an enemy ship is sighted and comes within range, it is the function of fire control to solve the fire control problem so that your ship's weapons will hit the target. If the enemy was obliging enough to remain in one place and your ship was also brought to a stop, the required elevation and train angles could be determined by considering only the factors of interior and exterior ballistics for fixed gun and target discussed on the preceding pages. No enemy ship would be foolish enough to remain still under fire; and your own ship doesn't want to be a "sitting duck" for the enemy's fire either. Therefore, both the target and your own ship will keep moving during battle. As a result, the target range and bearing are continually changing, necessitating constant changes to gun elevation angle and gun train angle.

Referring to the illustration below, you can see that in order to make the proper corrections, it is necessary to know in what direction and at what speed the target is moving. With this information, it is possible to predict the position the target will occupy after the time of flight of the projectile has elapsed. The weapon is then directed so that the projectile will strike the future position of the target.

Another factor which must be considered in the fire control problem when both ships are moving is the fact that the velocity of the ship will be imparted to the projectile at the instant of firing, and will affect the trajectory. To illustrate this effect, consider the target as standing still and the firing ship in motion. As the gun is fired, the projectile has two velocities, its own I. V. and that due to the ship's motion. If the ship's velocity is not considered, the projectile will land short, beyond, or to one side of the target. Where the projectile lands depends on whether the ship is leaving, approaching, or moving laterally with respect to the target. You can see that the effect of ship's speed and direction must be considered to obtain accurate fire.

EFFECTS OF DECK MOTION - Another factor which enters into the solution of the fire control problem on moving ships is the fact that the deck which supports the gun is very seldom perfectly level. A moving ship requires that corrections be made to gun orders to compensate for deck motion. Deck motion can be resolved into two motions: Roll and Pitch.



15. HOW TARGET MOTION AFFECTS RANGE AND BEARING

Roll is rotation of the ship from side to side in a plane perpendicular to the deck, through the ship's athwartships axis.

Pitch is rotation of the ship from bow to stern in a plane perpendicular to the deck, through the ship's centerline.

You can visualize, that as the ship rolls and pitches, the line of sight will be displaced. Before the fire control problem can be solved and gun orders computed, the effects of roll and pitch must be measured.

The effect of deck motion on elevation of the line of sight is called level. Level is the angle between the horizontal plane and the deck plane, measured in a vertical plane or a normal plane depending upon the type of stabilizing unit used. Level angle (Ei) is measured in the vertical plane through the line of sight. Level angle (Ei') is measured in the normal plane through the line of sight. Refer to OP 1700 for complete definitions.

The other effect of deck motion on the line of sight is called crosslevel. Like level, the measurement of crosslevel depends upon the type of stabilizing unit. Crosslevel angles are measured between vertical and normal planes. Crosslevel (Z) is the angle between the vertical plane through the line of sight, and the normal plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about the axis which is the intersection of the vertical plane through the line of sight and the horizontal plane. Refer to OP 1700 for complete definitions of crosslevel.

Because the directors and gun mounts are mounted in the deck plane, and therefore train and elevate with respect to the deck plane, the measurements of level and crosslevel are utilized to correct various data. These corrections include Deck Tilt, Deck Deflection, and Trunnion Tilt corrections.

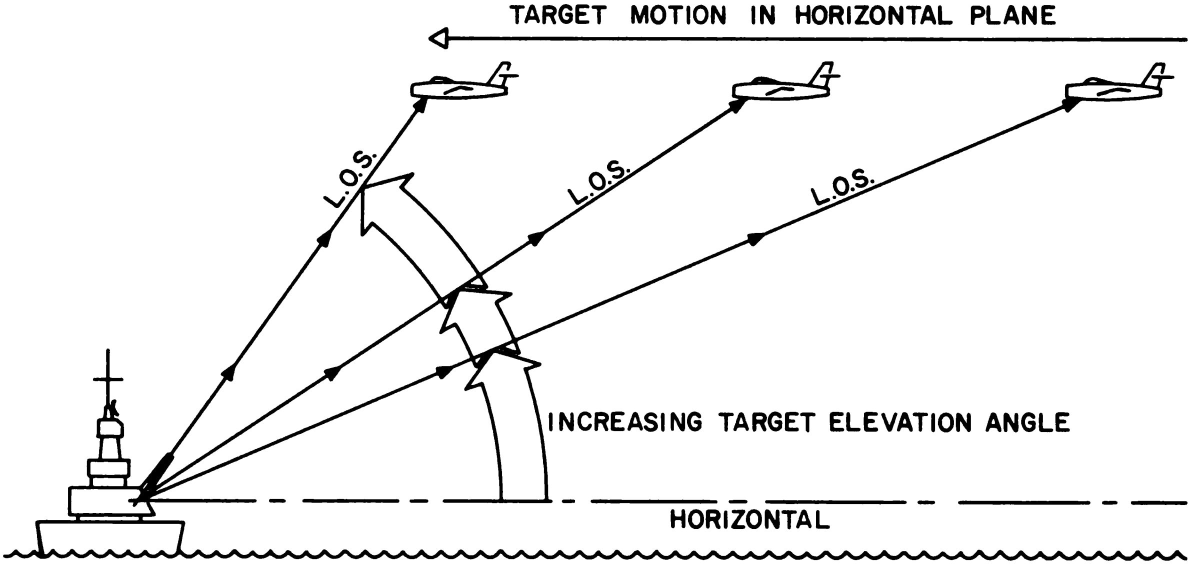
Present target position as measured by the director is referenced to the deck plane. Ballistic computations are normally referenced to the horizontal plane. The use of level and crosslevel to correct the deck plane measurements to the horizontal plane for computational purposes, is essentially known as Deck Tilt correction.

Deck Deflection and Trunnion Tilt corrections are essentially the use of level and crosslevel to correct ballistic computations in order to reorient gun orders to the deck plane.

The formulas and methods used are quite complex and vary with the system. For this reason you will not study them at this point in your training.

EFFECTS OF TARGET ELEVATION - The anti-aircraft problem, sometimes called the air problem, is another form or variation of the basic fire control problem. All of the factors that entered into the statement of the surface fire control problem must be considered in stating the air problem. The air problem is further complicated by the fact that the target is moving at high speed and may be either climbing or diving.

In the surface problem, the target elevation angle (between L. O. S. and horizontal) was zero because both own ship and target were on the ocean's surface, and the L. O. S., for all practical purposes, was in the horizontal plane. Air targets, however, are ordinarily well above the ocean's surface, so that the L. O. S. makes an appreciable angle with the horizontal. In addition, if the air target is approaching or leaving own ship in a horizontal plane, the L. O. S. must be

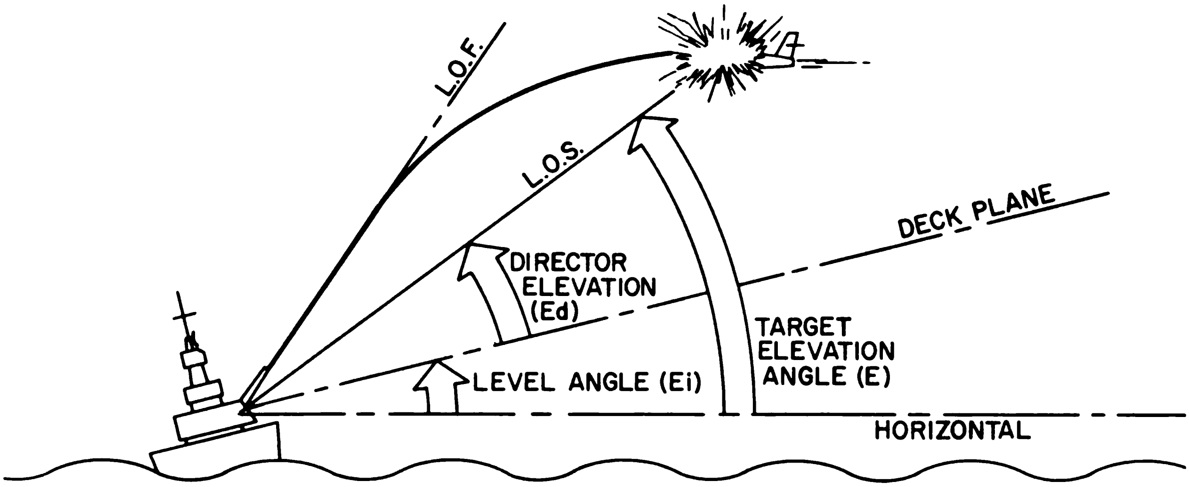

TARGET MOTION IN HORIZONTAL PLANE
L.O.S.
L.O.S.
L.O.S.
INCREASING TARGET ELEVATION ANGLE
HORIZONTAL

16. EFFECT OF MOVING TARGET ON TARGET ELEVATION ANGLE

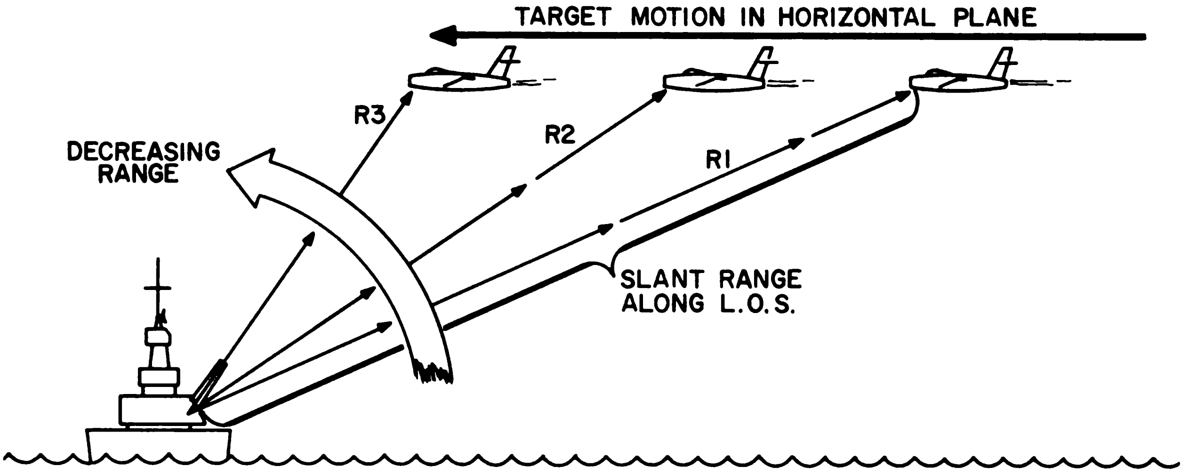
elevated or depressed to keep the target in view. Thus, target elevation angle continually increases or decreases and as it does so, the gun elevation order must be correspondingly altered. This effect is shown in the illustration above.

As shown in the illustration below, target elevation angle is determined by measuring director elevation at the director and combining this with the level angle measured by the stable element.

If we continue to consider the air target approaching the ship in a horizontal plane, you can see in the illustration on facing page that slant range from the director to target along the L. O. S. decreases as the target nears own ship. The reverse is true when the target is moving away from the ship. It



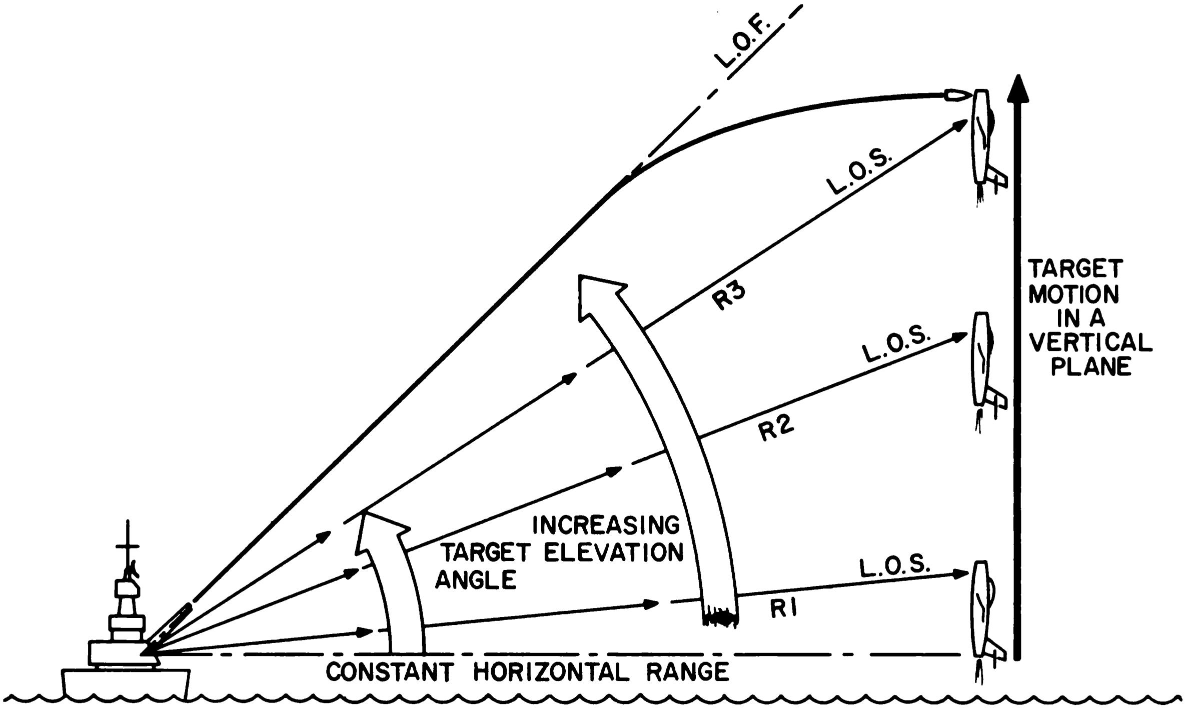
17. HOW TARGET ELEVATION ANGLE IS DETERMINED



18. EFFECT OF MOVING AIR TARGET ON RANGE

is slant range which is measured by the range finder or the radar. Both target elevation angle and range effect gun elevation order. They determine, along with the other ballistic corrections, what the sight angle (angle between the L. O. S. and the L. O. F.) must be in order that the projectile will intercept the target.

You have seen how an air target moving horizontally above the ocean, affects the fire control problem for air targets. The fact that the air target may also be climbing or diving must also be considered. The illustration below shows the effect of the target's vertical motion on gun elevation order. We


L.O.F.
L.O.S.
R3
L.O.S.
R2
INCREASING TARGET ELEVATION ANGLE
L.O.S.
R1
CONSTANT HORIZONTAL RANGE
TARGET MOTION IN A VERTICAL PLANE

19. HOW VERTICAL TARGET MOTION AFFECTS TARGET ELEVATION ANGLE AND RANGE

will consider a target which is moving only in a vertical plane so that the horizontal range from the ship is constant. The target elevation angle and the slant range both increase as the height of the target above the earth increases, and vice versa.

Of course, in actual practice, air targets will move both horizontally and vertically. Regardless of target motion, the anti-aircraft fire control system must be able to predict the future target range, bearing, and elevation, and make the necessary corrections to sight angle and sight deflection. You will recall that sight angle was defined as the angle between the L. O. S. and the L. O. F. Sight angle is the main factor which is added to director elevation to obtain gun elevation. Sight deflection is also an angle between L. O. S. and L. O. F. and is added to director train to obtain gun train.

REVIEW AND SUMMARY

The ability to lay out and solve fire control problems is one of the important requirements of all FTs. The mathematics you will have to know to solve the problem has been presented. The portion devoted to trigonometry and vectors will be of particular importance in solving the fire control problem.

The system of symbols for designating various quantities associated with the fire control problem was also introduced. . You should understand the use of the basic symbols and the various modifiers so as the various quantities are introduced in the following topic, you will be able to determine the basic meaning. Most of the factors which affect the accuracy of a projectile with respect to surface and air targets have been discussed. Underwater fire control and missile fire control require some modification to the problem but the basic problem remains the same. You are now ready to solve the fire control problem. Keep in mind the following general steps in solution of the fire control problem:

1. Determine present target position in relation to own ship.
2. Predict future target position in relation to own ship.
3. Stabilize the various units.
4. Calculate required corrections to train and elevation orders.
5. Transmit data to delivery device.

TOPIC 2: SOLVING THE FIRE CONTROL PROBLEM

YOU ARE NOW GOING TO LEARN:

1. How the fire control problem is solved in the Mk 68 GFCS.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Present position computation.
   a. Deck plane to horizontal plane conversion.
   b. Computation of horizontal range and target height.
   c. Computation of linear rates.
   d. Resolving true wind.
2. Prediction and ballistic computation.
   a. Establishing future target position.
   b. Correction for ballistic and motion quantities.
3. Trunnion tilt and parallax computation.
   a. Computing gun orders.
   b. Parallax corrections.
4. Fuze computation.
5. Review and summary.

INFORMATION AND DISCUSSION:

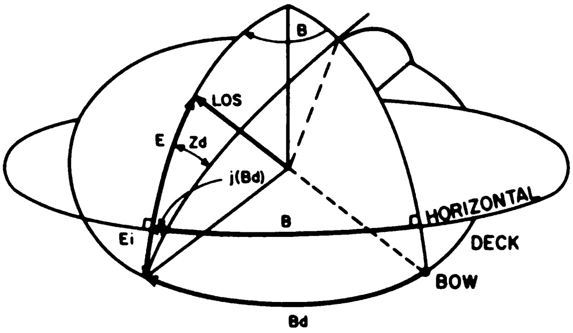
As stated earlier, there are variations in fire control problems and the methods by which they are solved. The references may vary from system to system, however, the same basic quantities are involved. In the material which follows, the Mk 68 GFCS will be used to illustrate the solution of the fire control problem. The fire control problem as solved by the computer is complex. Drawings will be used to illustrate the various steps in the solution. The solution of any fire control problem requires that a reference be established. In the Mk 68, as in most fire control systems, the horizontal plane will be the reference. Because the director is mounted in the deck plane, target position measured by the director is with respect to the deck. Conversion from deck to horizontal reference requires that director train Bd and director elevation Ed be modified by level Ei and crosslevel Zd which are measured by the stable element. The stable element is constructed in such a manner that crosslevel is measured with respect to the deck plane. Refer to OP 1700 and note the difference between crosslevel Zd and crosslevel Z.

PRESENT POSITION COMPUTATION

The present position section of the computer performs the following functions:

1. Converts target position from the deck plane to the horizontal plane.
2. Compares target position with generated target position.
3. Computes angular rates from the errors obtained in the above comparison.
4. Determines linear rates for use in the prediction and ballistic section.
5. Recombines the linear rates in order to generate continuously varying estimates of target present position.
6. Computes the stabilization aids for the director.

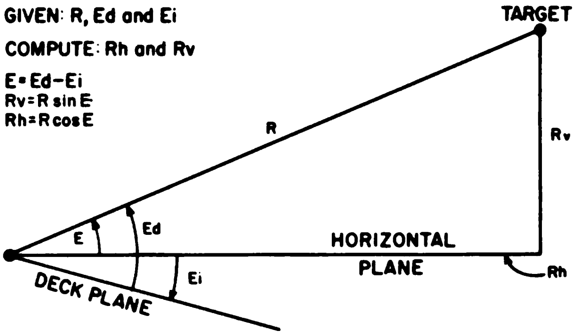
The geometrical values involved in conversion from the deck plane to the horizontal plane are shown below.



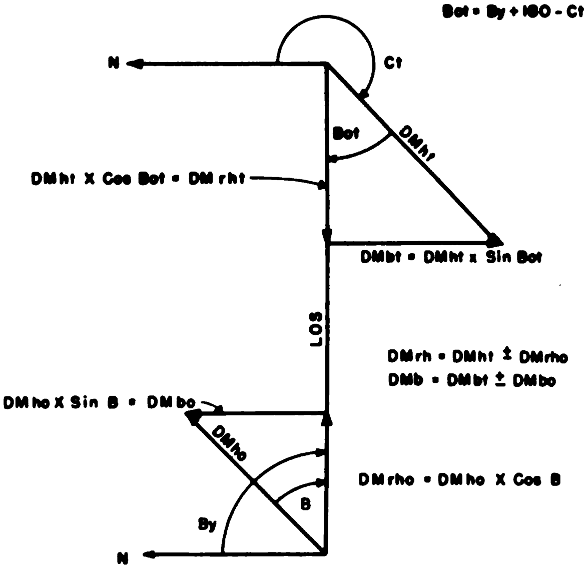
20. SPHERICAL COORDINATE DIAGRAM

When the deck plane and the horizontal plane coincide, relative target bearing (B) and director train (Bd) are equal. With the deck tilted by some amount (measured as level and crosslevel) and Bd at some angle other than 0 or 180 degrees, a deck tilt correction, j(Bd) is computed. B = Bd + j(Bd). The correction j(Bd) is dependent on both Ei and Zd. Addition of ship's course (Co) to B produces true target bearing By. Level Ei is subtracted from director elevation Ed to produce target elevation E.

With the target located in the horizontal plane, the next step is to compute horizontal range Rh and target height Rv. The quantities Rh and Rv will be used in later calculations. The illustration below illustrates the problem.



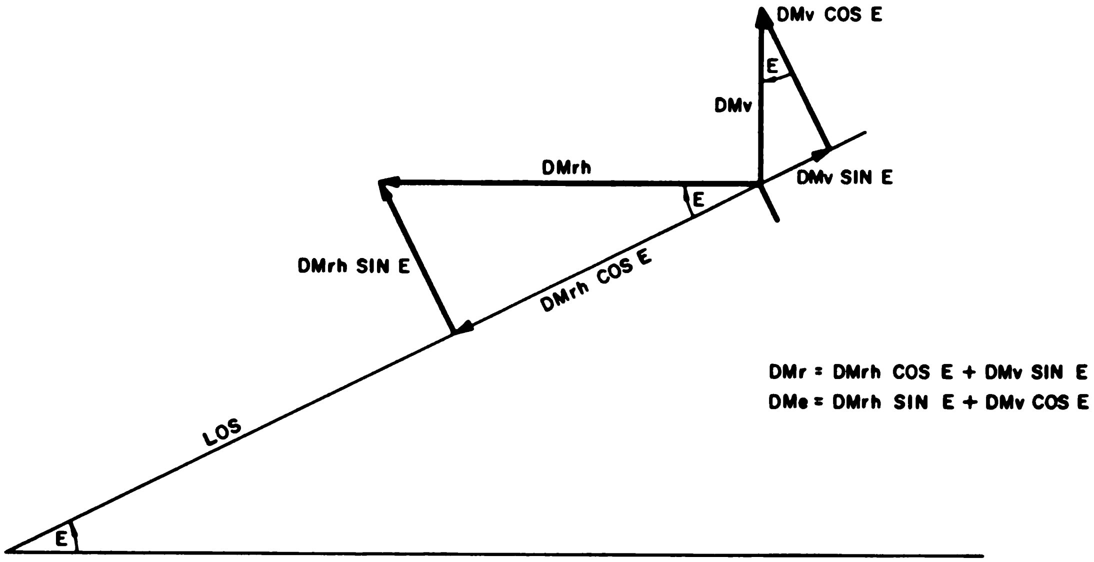
21. RECTANGULAR COORDINATE VALUES OF TARGET POSITION



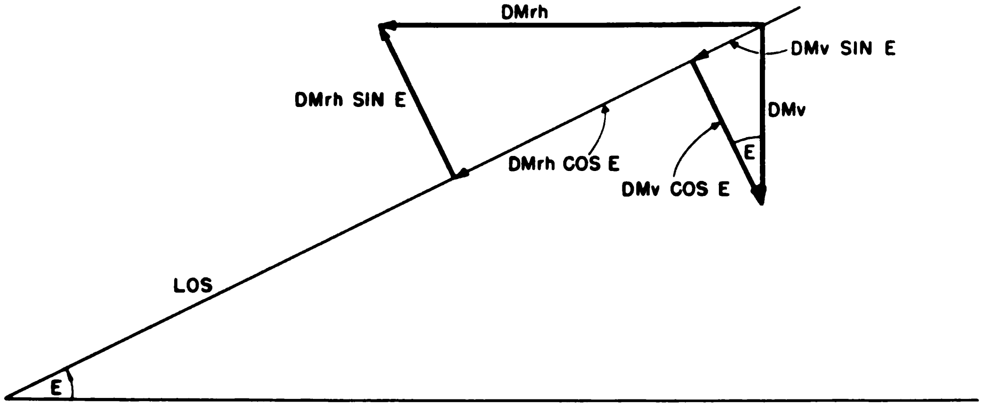
22. FIRE CONTROL PROBLEM HORIZONTAL PLANE

Another step, computation of linear rates in and across the L. O. S., is shown to the right. Own ship motion is represented by a vector whose magnitude is ship's speed DMho, and whose direction is relative target bearing B. Target motion is represented by a vector whose magnitude is target speed DMht, and whose direction is target angle Bot. Each vector is resolved into two components in the horizontal plane. One of these components will be along the line of sight and the other will be perpendicular to the line of sight. Horizontal range rate DMrh is found by algebraically adding the components along the L. O. S. Rate of linear movement in bearing (DMb) is found by algebraically adding the components perpendicular to the L. O. S.

As shown in the illustration below and on facing page, target motion must also be considered in the vertical plane. Rate of climb (DMv) measures the target's rate of vertical linear movement in elevation, DMrh, found previously, is used with DMv to construct the diagram in the vertical plane through the L. O. S. Components along the L. O. S. are added to produce present range rate (DMr). Components perpendicular to the L. O. S. are added to produce rate of linear movement in elevation (DMe).

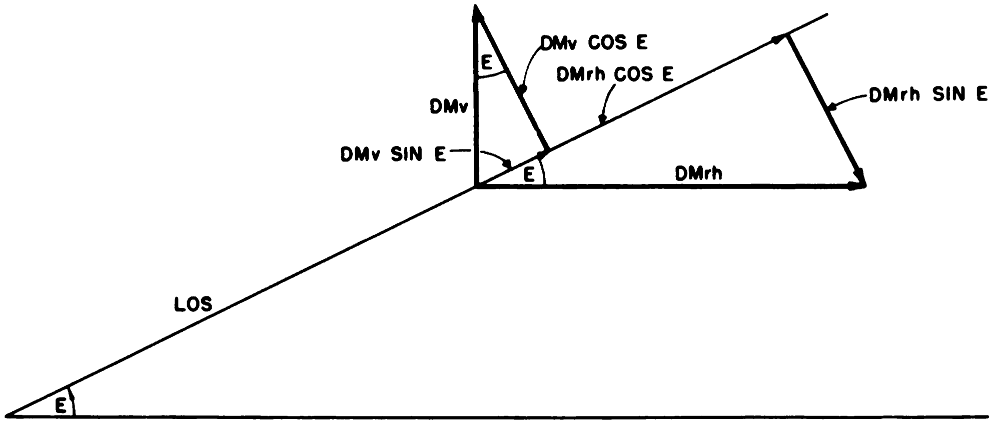


INCOMING TARGET, CLIMBING

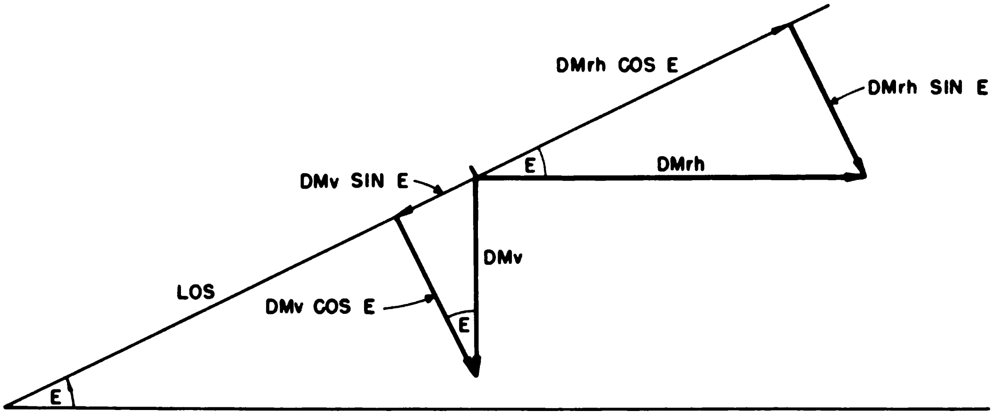


INCOMING TARGET, DIVING

23. FIRE CONTROL PROBLEM - VERTICAL PLANE



OUTGOING TARGET, CLIMBING

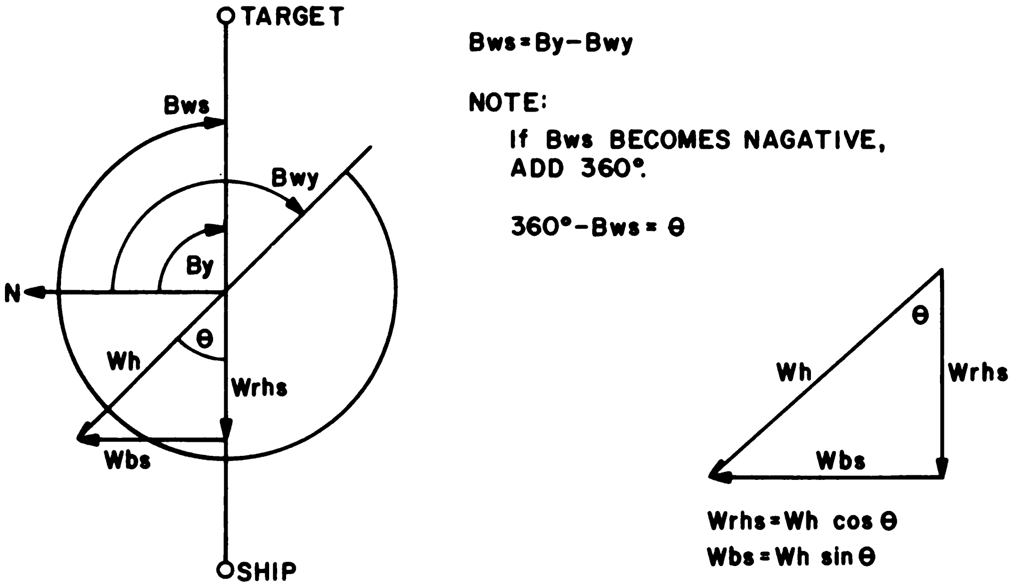


OUTGOING TARGET, DIVING

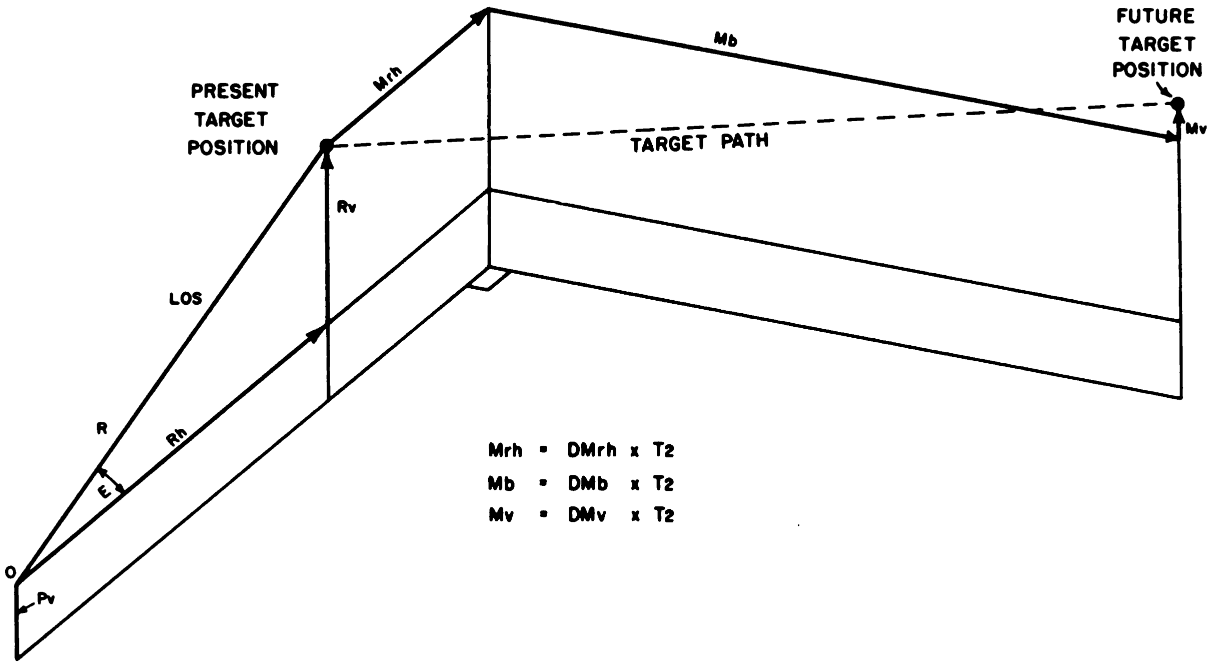
24. FIRE CONTROL PROBLEM - VERTICAL PLANE

The present position section of the computer also resolves True Wind in and across the L. O. S. as shown in the illustration below. The magnitude of true wind vector is wind speed Wh and the direction of the vector is true direction of true wind (Bwy).

With high speed air targets, little time is allowed for engagement. It is necessary therefore for the computer to act rapidly and completely automatically to determine the target course, speed, and rate of climb. These quantities, Ct, DMht, and DMv, must be determined by the computer. The computer uses a process called rate control to determine these quantities. The process is quite involved and will not be discussed in this Trainee's Guide. Basically what is done is to compare generated values against computed or observed values. The difference or error in the comparison is a rate control signal used to correct the generated values.



25. L. O. S. COMPONENTS OF TRUE WIND



26. ESTABLISHING FUTURE TARGET POSITION

PREDICTION AND BALLISTIC COMPUTATION

The function of the prediction and ballistic section is to compute a line of fire (L. O. F.) which is oriented with respect to the L. O. S. and the horizontal plane. This section computes:

1. The position the target will occupy at the end of the time of flight.
2. The amount the guns must lead this point so the projectile will hit the target.

As shown above, future position is determined by first multiplying the relative motion rates DMv, DMrh, and DMb by an assumed time of flight, T2, and combining the linear quantities with present target position values Rh and Rv. The solution of correct T2 will be discussed later.

Calculation of gun bearing Bg and gun elevation Eg requires corrections for the various ballistic and motion quantities. The illustrations below and on the facing page show the line of fire.

Horizontal deflection Lh is obtained by combining horizontal angular motion Sh and wbq(Lh), the total horizontal deflection angle due to wind, drift, and spot. Lh, if combined with relative target bearing B, would produce relative gun bearing Bg. In the Mk 68, however, these quantities are not combined in the prediction and ballistics section but will be utilized in the trunnion tilt section.

Gun elevation Eg is the sum of target elevation aiming position angle (E4) and superelevation angle (V4).

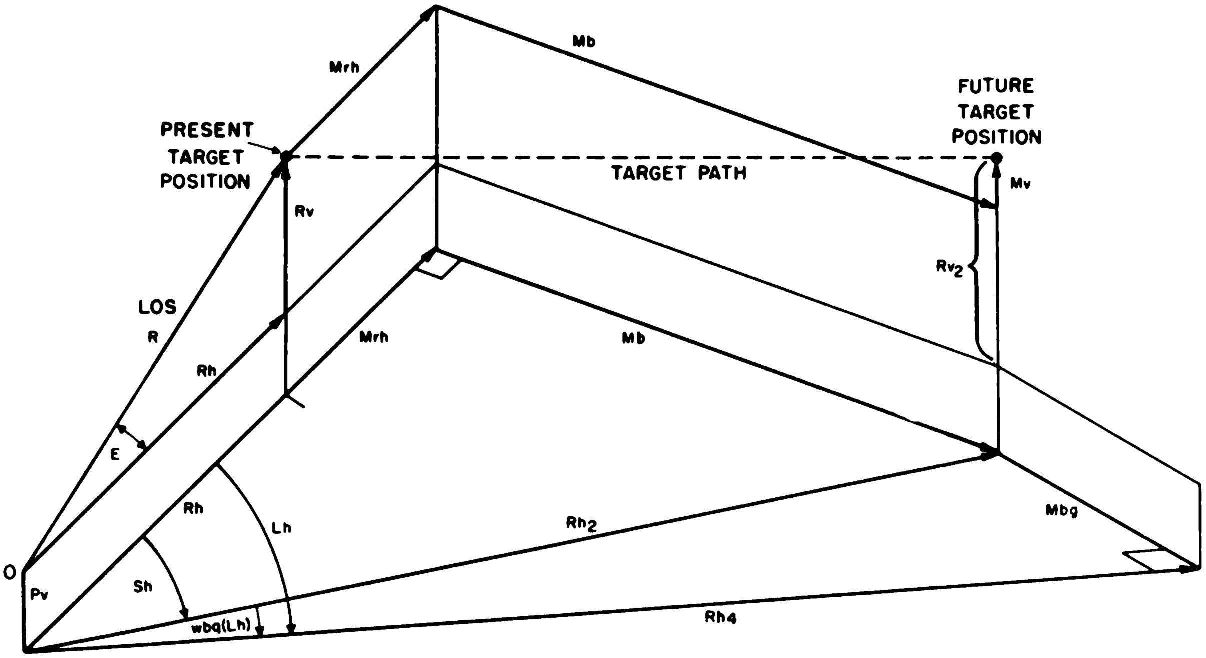
E4 is determined by the solution of a triangle formed as follows: Target height Rv, vertical parallax displacement Pv, and vertical linear movement Mv are combined to form H4, the side of the triangle opposite E4. The adjacent side is horizontal range to aiming point (Rh4).

V4 is determined by the solution of a triangle formed as follows: Superelevation for normal conditions, b(V4); corrections and partial corrections to superelevation due to initial velocity, u(V4); air density, x(V4); apparent wind, w(V4); and elevation spot, q(Eg) are combined to form the side opposite V4. The adjacent side is aiming point range, R4. Note: q(Eg) is not used for air targets.

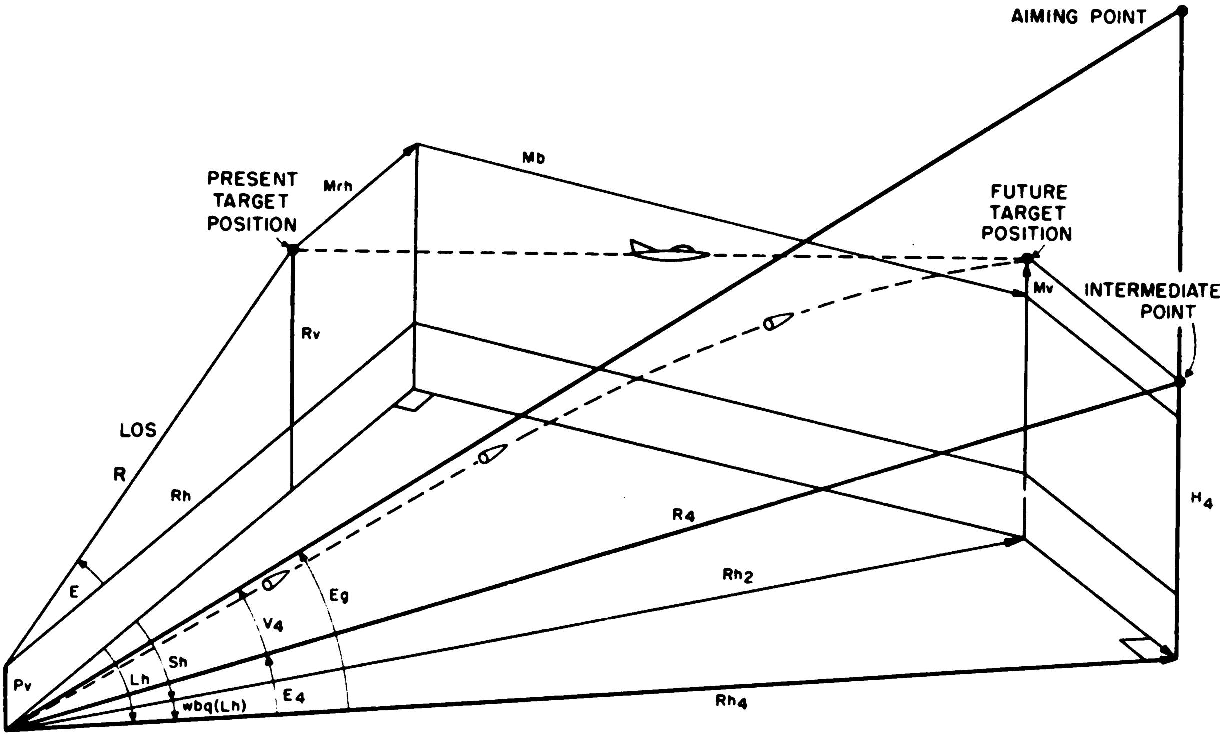
Time of flight T2 is calculated in this section by a closed loop system. The assumed value of T2 is compared to R4 and E4 and corrected until it agrees. Corrections for wind, initial velocity, and air density are applied to T2 and the above process for computing T2 is repeated.

TRUNNION TILT AND PARALLAX COMPUTATION

The trunnion tilt section computes the gun orders which are transmitted to the gun mounts. The guns are mounted on trunnions which provide the axis about which the guns are free to move in elevation. The trunnions are rotated as the mount is trained. Unless the deck plane and horizontal plane coincide (Ei and Zd = 0), the quantities Lh and Eg must be modified to make up gun orders Bdg' and Edg'. The following illustrations on the facing page illustrate the effect of and the

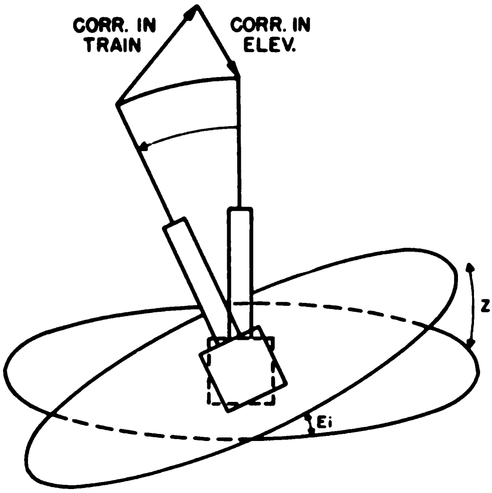


27. LINE OF FIRE IN HORIZONTAL PLANE

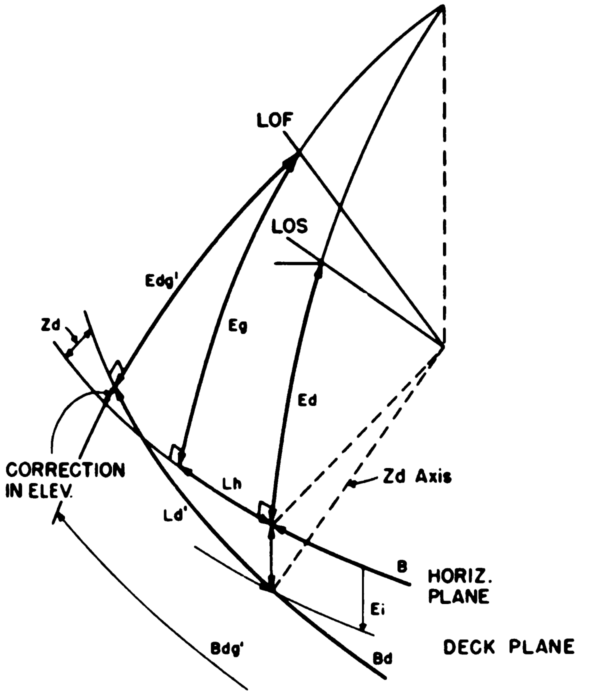


28. LINE OF FIRE IN VERTICAL PLANE

correction for trunnion tilt. Gun train order Bdg' and gun elevation order Edg' are transmitted to the guns by synchros.



29. EFFECTS OF TRUNNION TILT



30. CORRECTIONS FOR TRUNNION TILT

If all guns were physically located at the reference point, the director, projectiles fired from the guns would hit the target without further correction. The guns are, of course, not located at the reference point but are some distance forward or aft of the reference point and also below it.

The parallax difference due to the height of the director above the guns is considered in the problem as a portion of advance position height, H4, and therefore affects the computation of advance elevation position angle, E4, and consequently gun elevation order Edg' as it is transmitted by the computer. This height difference is considered the same for all guns, 10 yards.

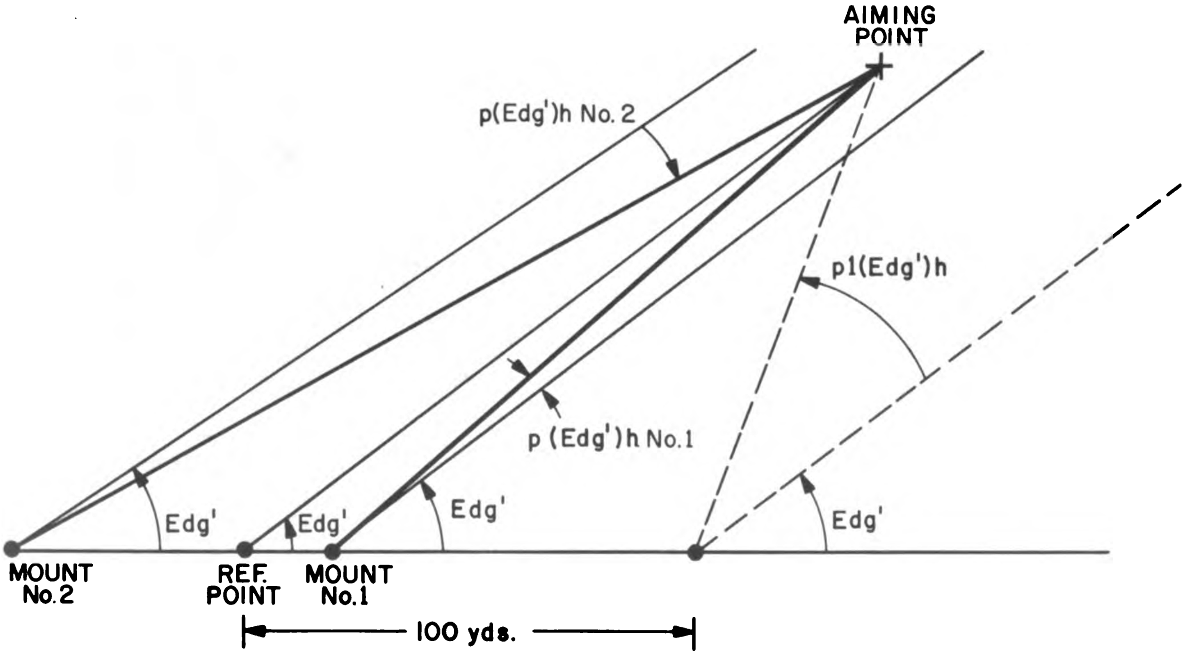
As shown below, another quantity must be added to Edg' to compensate for the horizontal displacement of the guns from the director. The nomenclature for this quantity as transmitted by the computer is p1(Edg')h. This can be broken down as follows:

1. The Edg' in parenthesis shows that the quantity is a correction to gun elevation order.
2. The quantity modifier p denotes a parallax correction.
3. The numeral one used as a quantity modifier means unit parallax, or that parallax correction necessary for a one hundred yard parallax base length forward of the reference point.
4. The quantity modifier h means that this correction is due to a horizontal displacement of the gun from the director.

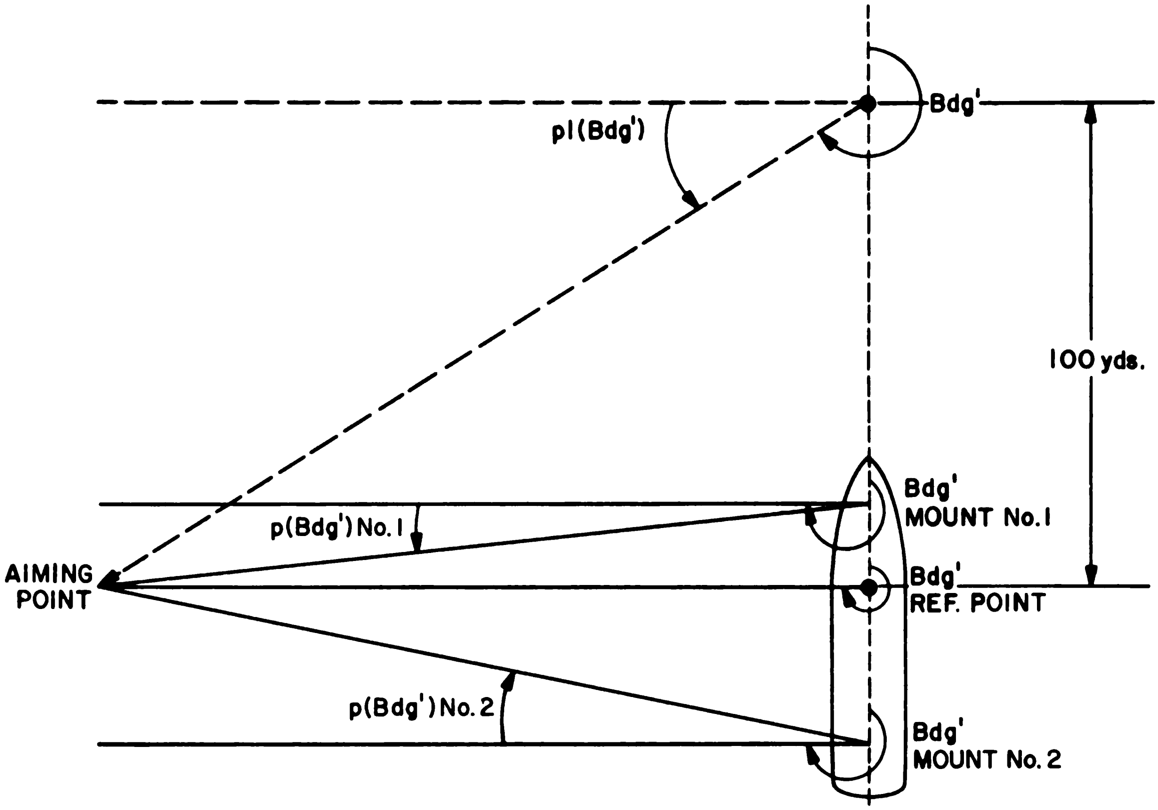
The quantity transmitted is therefore unit elevation parallax correction, p1(Edg')h.

When computing p1(Edg')h, three quantities already computed must be considered. These three variables are E4, R4, and Bdg'. These quantities are used as follows:

1. Since the guns are mounted along the base length fore and aft of the director, it can be seen that p1(Edg')h will be zero when elevation is zero and would have to compensate for the entire base length error at 90 degrees. This



31. EFFECTS OF ELEVATION PARALLAX CORRECTION



32. EFFECTS OF TRAIN PARALLAX CORRECTION

means that pl(Edg')h must vary as the sine function of elevation angle. The value used is sine E4, sine of target elevation aiming position.

2. Parallax errors decrease as range increases and conversely increase with a decrease of range. Causing the correction to change with the reciprocal of R4, aiming range, compensates for this.

3. The correction to Edg' will also vary as the cosine of Bdg', gun train order, since it will be zero at the beams and maximum fore and aft.

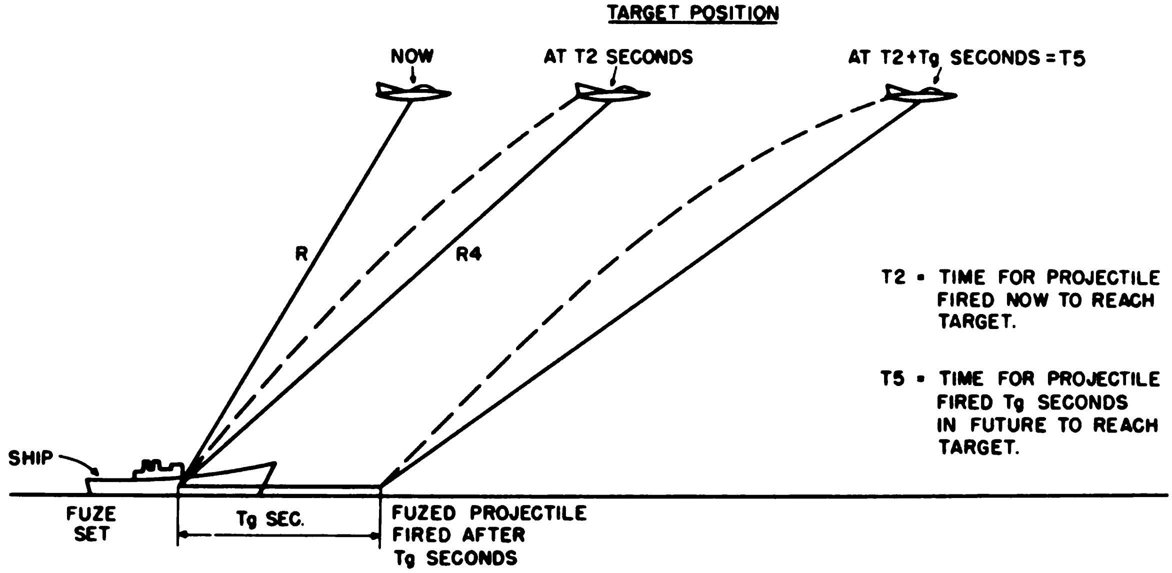
The guns are, of course, not all one hundred yards forward of the director. The direction of the correction is reversed in transmission to mounts aft of the director. Only that portion of unit parallax needed for the actual base length of the gun from the reference is used as a correction to Edg'. The amount is selected through the use of change gears in the receiving unit of the gun mount. The correction is now represented as p(Edg')h, the numeral one having been dropped as a quantity modifier since the unit base of 100 yards is no longer used.

As shown above, the horizontal displacement of the guns fore and aft from the director also necessitates corrections to Bdg', gun train order, as used by the individual guns. The basic correction transmitted by the computer is pl(Bdg'). This can be broken down as follows:

1. Bdg' in parenthesis denotes a correction to be applied to gun train order.

2. The quantity modifier p denotes a parallax correction.

3. The numeral one used as a quantity modifier denotes unit parallax computed for a base length of 100 yards.


TARGET POSITION
NOW
AT T2 SECONDS
AT T2+Tg SECONDS = T5
R
R4
T2 = TIME FOR PROJECTILE FIRED NOW TO REACH TARGET.
T5 = TIME FOR PROJECTILE FIRED Tg SECONDS IN FUTURE TO REACH TARGET.
SHIP
FUZE SET
Tg SEC.
FUZED PROJECTILE FIRED AFTER Tg SECONDS

33. FUZE COMPUTATION

The quantity transmitted is p1(Bdg'), unit train parallax due to horizontal base.

When computing p1(Bdg'), the three variable quantities that must be considered are R4, E4, and Bdg'. They are used as follows:

1. p1(Bdg')is caused to vary with the reciprocal of R4.
2. Since train parallax errors are maximum on the beams, and zero fore and aft, p1(Bdg') varies as the sine of Bdg'.
3. p1(Bdg') must increase as target elevation position angle increases. In this case the secant function of E4 is used for that increase because the gun is trained in the deck plane.

The unit parallax quantity, p1(Bdg'), is corrected in the receiving unit of the gun mount for actual parallax base length of the gun and direction of correction. Change gears pick off the correct amount and synchro receiver connections are such that the correction is applied in the proper direction. The quantity then becomes p(Bdg'), the numeral one having been dropped to show that the quantity is no longer unit parallax.

FUZE COMPUTATION

The function of the fuze computer is to compute a fuze order setting T5. If the fuze could be set at the instant of firing, T5 would be equal to time of flight T2. Unfortunately there is some delay. The delay is dead time Tg. The illustration above illustrates the problem to be solved.

Computation of the fuze order completes the sequence for solving the fire control problem. Only major steps of the solution were illustrated, however, you should at this time have a good general understanding of the problem and how fire control equipment solves the problem.

QUIZ:

1. Solve by addition:

$\begin{array}{r} 4 \\ \underline{-6} \end{array}$ $\qquad$ $\begin{array}{r} -23 \\ \underline{-16} \end{array}$ $\qquad$ $\begin{array}{r} -7 \\ \underline{4} \end{array}$

$\begin{array}{r} 13.04 \\ \underline{-7.39} \end{array}$ $\qquad$ $\begin{array}{r} .0130 \\ \underline{-1.2186} \end{array}$

$\frac{3}{4} + \frac{1}{2} =$ $\qquad$ $\frac{2}{3} - \frac{1}{2} =$

$\frac{-7}{8} + 1\frac{3}{4} =$

$\frac{-5}{6} + \frac{1}{24} =$

$\frac{-7}{8} + \frac{17}{32} - \frac{3}{4} + \frac{1}{2} =$

2. Solve by subtraction:

$\begin{array}{r} -9 \\ \underline{3} \end{array}$ $\qquad$ $\begin{array}{r} 5 \\ \underline{-3} \end{array}$ $\qquad$ $\begin{array}{r} -8 \\ \underline{-9} \end{array}$

$\begin{array}{r} 31.47 \\ \underline{-\ \ 2.90} \end{array}$

$1\frac{3}{4} - \frac{7}{8} =$

3. Perform the indicated operations:

$3 \times 4.8 =$ $\qquad$ $67 \cdot 4 =$

$(4)(36)(.05) =$

$\frac{-2}{3} \times \frac{-1}{2} =$ $\qquad$ $\frac{5}{6} \times \frac{1}{8} =$

$-1.5 \times .003 =$ $\qquad$ $\frac{-125}{-4} =$

$25.5 \div 5 =$ $\qquad$ $\frac{2}{3} \div \frac{1}{4} =$

$-27.76 \div .02 =$

$\frac{-.0000782}{200} =$

$16^2 =$ $\qquad$ $8^3 =$

$5^5 =$ $\qquad$ $2^3 \cdot 2^5 =$

$3^{-4} \cdot 3^2 =$

$\frac{8^4}{8^2} =$ $\qquad$ $\frac{3^3}{3^4} =$

$\frac{29^5}{29^5} =$ $\qquad$ $\sqrt{2} \cdot \sqrt{3} =$

$\sqrt{9} \cdot \sqrt{9} =$ $\qquad$ $\frac{\sqrt{10}}{\sqrt{5}} =$

$36^{\frac{1}{2}} =$ $\qquad$ $8^{\frac{1}{3}} =$

4. **Perform the indicated operations:**

$81^{\frac{1}{2}} =$

$\sqrt{75} =$

$4\sqrt{3} + 6\sqrt{3} - 2\sqrt{3} =$

$2\sqrt{5} + 5\sqrt{2} + 4\sqrt{5} =$

$$\frac{2 \times 10^{2} - 4 \times 10^{3} + 6 \times 10^{3}}{2 \times 10^{4}} =$$

$$\frac{(6 \times 10^{3})(3 \times 10^{4})}{9 \times 10^{2}} =$$

$$\frac{(3 \times 10^{-3})(3 \times 10^{-2})}{3 \times 10^{-7}} =$$

$$\frac{(2 \times 10^{-8})(2 \times 10^{8})}{(3 \times 10^{2})(2 \times 10^{-4})} =$$

5. **Find the square roots:**

$\sqrt{4664.89}$

$\sqrt{4.7961}$

$\sqrt{.002809}$

6. Perform the indicated operations:

$(a - 3)(a + 2) =$

$(x + 5)(x - 5) =$

$\left(5B - \frac{1}{3}\right)\left(3B + \frac{1}{5}\right) =$

$(xy + 2)(xy + 3) =$

$(x - y)(x + y) =$

$(a + b)^2 =$

$(x - y)^2 =$

$(x - 2)(x^2 + 2x - 4) =$

$\frac{a^3 + a^2 - 3a + 1}{a - 1} =$

7. Factor:

$x^2 - z^2 =$

$c^2 - d^2 =$

$x^2 + 2ax - 4x =$

$18m^2n^4 + 6m^2n^2 - 36m^2n^3 =$

$xy - 5x + ty - 5t =$

$xy - xz - wz + yw =$

$x^2 - 2x - 35 =$

8. Solve for X:

$x^2 + x - 6 = 0$

9. Solve for X:

$$x^3 + 3x^2 - 18x = 0$$

11. Solve for X:

$$\frac{6}{x} + x = 5$$

10. Solve for Y:

$$2.5x^3y^2 + 4x^2y + 3xy^3 = 0$$

$$x = 2$$

$$6x^2 + 7x - 5 = 0$$

$$2x^2 - 6x + 3 = 0$$

12. Solve as indicated:

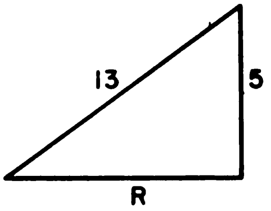
$A^2 = B^2 + C^2$ Solve for C

$X = \frac{Y^2}{Z}$ Solve for Y

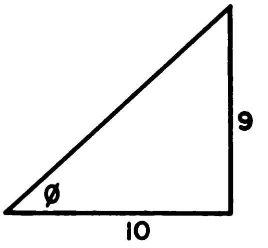
$A = \frac{2\pi}{B\sqrt{CD}}$ Solve for D

$\frac{1}{L} = \frac{1}{M} + \frac{1}{N} + \frac{1}{P}$ Solve for P

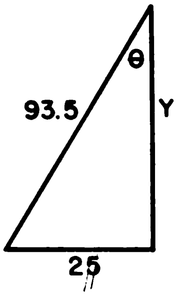
13. Solve for R:



14. Solve for ϕ:



15. Solve for θ and Y:



16. Solve the following vector problems as indicated:

Given: $\bar{R} = \bar{A} + \bar{B}$

$\bar{A} = 7 + 6$

$\bar{B} = 3 - 8$

Solve for $\bar{R}$ in rectangular form

$\bar{A} = -9 + 3$

$\bar{B} = 8 \angle 40^\circ$

Solve for $\bar{R}$ in rectangular form

$\bar{A} = 7.32 - 3$

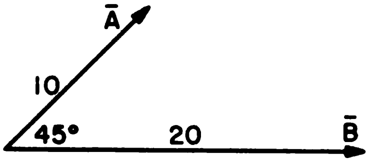
$\bar{B} = -24.64 + 8$

Solve for $\bar{R}$ in polar form

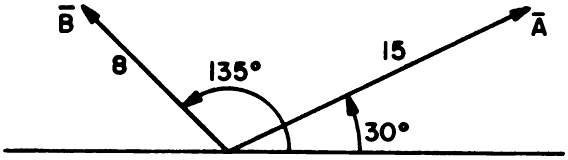
$\bar{A} = 9 \angle 40^\circ$

$\bar{B} = 6 \angle 10^\circ$

Solve for $\bar{R}$ in rectangular form



Solve for $\bar{R}$ in rectangular form



Solve for $\bar{R}$ in polar form

17. In your own words define the following:

Bgy

DMro

ic(B)

18. Write the symbols necessary to describe the following:

An angle measured in the deck plane from the bow to a vertical plane through the line of fire.

An angle from the horizon to the target from the director when Ei and Zh are zero.

A vector that represents that component of horizontal distance to the target that is in the East-West vertical plane.

19. Define ballistics.

20. What are the two classifications of ballistics?

21. Where in the gun bore does the most erosion take place?

22. How does bore erosion affect the fire control problem?

23. The path a projectile takes from the gun to the target is called the __________________________________.

24. Describe the effect of gravity on a projectile fired from a gun.

25. How is the effect of air resistance related to the size and velocity of a projectile?

26. What is drift?

27. What means is used to compensate for range wind?

28. Define apparent wind.

29. How does own ship's motion effect the fire control problem?

30. Define:

Roll

Pitch

Level

Crosslevel

31. Solve for the unknown and plot the angles:

B = 60^o, Cqo = 30^o, By =

B = 90^o, Cqo = 0^o, By =

B = 30^o, Cqo = 90^o, By =

By = 60^o, B = 30^o, Cqo =

By = 30^o, B = 0^o, Cqo =

32. Solve for the unknown and plot the angles:

By = 0^{o}, B = 60^{o}, Cqo =

By = 60^{o}, Ct = 30^{o}, Bot =

By = 180^{o}, Ct = 270^{o}, Bot =

By = 120^{o}, Ct = 135^{o}, Bot =

By = 120^{o}, Bot = 60^{o}, Ct =

By = 130^{o}, Bot = 120^{o}, Ct =

By = 295^{o}, Bot = 35^{o}, Ct =

B = 120^{o}, Cqo = 80^{o}, Ct = 240^{o}

By = Bot =

By = 200^{o}, Cqo = 135^{o}, Ct = 260^{o}

B = Bot =

33. Plot and solve:

Given:

B = 315 deg.
Bot = 340 deg.
By = 70 deg.
DMho = 25 knots
DMht = 10 knots

Find:

Ct =
DMbo =
DMbt =
DMrho =
DMrht =
DMrh =
DMb =

34. Plot and solve:

Given:

B = 60 deg.
Bot = 120 deg.
By = 90 deg.
DMho = 30 knots
DMht = 28 knots

Find:

DMrho =
DMrht =
DMbo =
DMbt =
DMrh =
DMb =

35. Plot and solve:

Given:

B = 245 deg.

Bot = 315 deg.

Cqo = 45 deg.

DMho = 20 knots

DMht = 15 knots

Find:

DMrho =

DMrht =

DMbo =

DMbt =

DMrh =

DMb =

36. Plot and solve:

Given:

Bot = 135 deg.

B = 35 deg.

By = 230 deg.

DMho = 18 knots

DMht = 12 knots

Find:

Ct =

DMbo =

DMbt =

DMrho =

DMrht =

DMrh =

DMb =

37. Plot and solve:

Given:

Cqo = 90 deg.
B = 110 deg.
Bot = 40 deg.
DMho = 28 knots
DMht = 25 knots

Find:

By =
Ct =
DMbo =
DMbt =
DMrho =
DMrht =
DMrh =
DMb =

38. Plot and solve:

Given:

Bot = 255 deg.
By = 20 deg.
Cqo = 70 deg.
DMht = 22 knots
DMho = 15 knots

Find:

Ct =
B =
DMbo =
DMbt =
DMrho =
DMrht =
DMrh =
DMb =

39. Plot and solve:

Given:

Bot = 5 deg.

B = 20 deg.

Cqo = 40 deg.

DMht = 25 knots

DMho = 40 knots

Find:

Ct =

By =

DMbo =

DMbt =

DMrho =

DMrht =

DMrh =

DMb =

40. Plot and solve:

Given:

Cqo = 245 deg.

Ct = 200 deg.

By = 320 deg.

DMho = 32 knots

DMht = 30 knots

Find:

B =

Bot =

DMbo =

DMbt =

DMrho =

DMrht =

DMrh =

DMb =

41. Plot and solve:

Given:

DMrh = 150 knots

DMv = -100 knots

E = 30 deg.

Find:

DMrh sin E =

DMrh cos E =

DMv sin E =

DMv cos E =

DMe =

DMr =

42. Plot and solve:

Given:

DMrh = 200 knots

DMv = 150 knots

E = 45 deg.

Find:

DMrh sin E =

DMrh cos E =

DMv sin E =

DMV cos E =

DMr =

DMe =

43. Plot and solve:

Given:

DMrh = -100 knots

DMv = -50 knots

E = 40 deg.

Find:

DMrh sin E =

DMrh cos E =

DMv sin E =

DMv cos E =

DMr =

DMe =

44. Plot and solve:

Given:

B = 60 deg.

Bot = 120 deg.

DMho = 20 knots

DMht = 30 knots

E = 45 deg.

DMv = 100 knots

Find:

DMrh =

DMb =

DMr =

DMv =

45. Plot and solve for the unknown:

By = 120°, Bwy = 60°, Bws =

By = 240°, Bwy = 140°, Bws =

By = 330°, Bwy = 100°, Bws =

By = 20°, Bwy = 240°, Bws =

46. Plot and solve:

Given:

Bws = 60 deg., Wh = 20 knots

Find:

Wbs =

Wrhs =

Given:

Bws = 125 deg., Wh = 10 knots

Find:

Wbs =

Wrhs =

Given:

By = 115 deg., Bwy = 90 deg.

Wh = 5 knots

Find:

Wbs =

Wrhs =

Section 3

WEAPONS SYSTEMS

Topic No.	Topic Title	Page
1.	Introduction	106
2.	Control Units	110

TOPIC 1: INTRODUCTION

YOU ARE NOW GOING TO LEARN:

1. What the weapon system concept is.
2. How ordnance equipment is identified.
3. The purpose of various weapon system components.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Weapon system concept.
    a. Definition.
    b. Parts.
    c. Your career - a system.
2. Identification of ordnance equipment.
    a. Mk and Mod.
    b. JAN system.
    c. Nameplates.
3. Weapon system components.
4. Review and summary.

INFORMATION AND DISCUSSION:

WEAPON SYSTEM CONCEPT

A weapon system is defined as the combination of a weapon (or multiple weapons) and the equipment used to bring the destructive power of the weapon against the enemy. To be more specific, a weapon system must include:

1. Units which detect, locate, and identify the target.
2. Units which deliver or initiate delivery of the destructive device or weapon to the target. (The term weapon is used flexibly in different contexts; for example, a gun is a weapon which delivers a projectile to the target, while a mine is a weapon that explodes when a target activates it.)
3. Units that control a delivery unit or weapon to direct its delivery; that set the fuze (or equivalent) of the destructive device; or (as with a torpedo) that program or preset a target-seeking device as required for maximum effectiveness in reaching the target.
4. Destructive units (usually termed weapons) which will destroy the target when in contact with it or when in its vicinity.

It is very important that you begin your career as a Fire Control Technician by developing the habit of thinking in terms of a complete system. It is probable that your first assignment as an FT will either be working on some particular fire control equipment or attending school on one of the equipments. You will not be able to effectively accomplish your assignment unless you consider the entire weapon system. Your knowledge of a particular equipment is not complete until you know how it works, how to keep it working, and how it ties in with the system. All too frequently you will find people who think only of the radar or computer or some other small part of the system. The weapon system cannot function effectively unless all equipments are treated as part of a whole, which must tie together.

Now is also the time to impress upon you, the trainee, that your whole future as an FT can be thought of as a system. Each lesson that you study is an integral portion of the system (foundations or building blocks) and you progress from the simple to the complex. Special Circuits is not separate from Electronics and Electronics is not separate from Electricity. The fundamentals that you learn in Electricity will be used in Electronics and applied in Special Circuits. The knowledge that you gain in this school will be used and broadened by your experience in the fleet as well as any other school you may attend. START NOW, AND CONTINUE TO THINK - SYSTEM. In the material which follows, you will be introduced to some of the various fire control systems. The term system will often be applied to areas of equipment such as the computing system. You must remember, however, that these so called systems are really only a part of a larger fire control system and further a part of the entire weapons system.

IDENTIFICATION OF ORDNANCE EQUIPMENT

The standard nomenclature for any item of naval ordnance equipment includes a basic noun, often accompanied by descriptive adjectives, plus identifying numbers, or letters and numbers. Identification by mark (Mk) and modification (Mod) is standard usage for weapons, fire control equipment (other than radar and other electronic gear), and principle components of these. Radar, sonar, and other electronic equipment use JAN (Joint Army Navy) system of letters and numbers; however, you will find some of the older fire control radars still in use are identified by Mk and Mod. For example: Mk 25 Mod 3.

The Mk (mark) number identifies a major item (like a gun mount or entire fire control system) or a principle component (like a sight or a director) of a particular design. For example: Gun Fire System Mk 37 includes a Radar Mk 25 and a Computer Mk 1A. When the Navy makes a basic change in design, or designs new equipment of the same general type, the name remains the same but a new mark number replaces the old.

The Mod (modification) number indicates a minor change or alteration.

Identification under the JAN system is fundamentally composed of two groups of letter prefixes followed by an identifying number. For example: Radar Set AN/SPS-48. The letter group "AN" means that the nomenclature complies with the system adopted jointly by the U.S. armed forces and does not necessarily mean it is used by more than one branch of the armed forces. In the group "SPS", the first "S" identifies the type of installation (here it is water surface craft), the "P" is the type of equipment (in this case radar), and the second "S" indicates the purpose (for this equipment, detecting and/or range and bearing). The number "48" serves as a model number, or the equivalent of a mark number. No modification numbers are used in the JAN system, instead a letter suffix "A", "B", etc. follows the model number. For example: AN/SPG-55B.

Nameplates and other means for identifying equipment - Each item of equipment bears a metal nameplate secured to some easily visible spot on its exterior. This plate is engraved or otherwise marked to provide the following information:

1. Standard nomenclature of the equipment, including mark and mod or equivalent, and identification of the system of which it is a part (unless it is an individual self-contained item).
2. Standard Navy Stock Number, Federal Stock Number, or other catalog identification.
3. Name of cognizant bureau (i.e. the Navy agency that procured the unit).
4. Manufacturer's part number or drawing number.
5. Name of manufacturer and number of contract under which the equipment was supplied.
6. Serial number, assembly, or other numbers which identify the specific unit. Items produced in large quantities may have a lot number instead of a serial number.

The nameplate will probably also contain other information, such as the voltage and frequency of electric power to be supplied to the unit, precautions to be observed in using it, and blanks for recording alterations that have been made etc.

There may be slight variations in the nameplates but they will be the best primary source for identification of the equipment. Nameplates must never be detached, defaced, obliterated, or permitted to become illegible, either through neglectful accumulation of dirt, being painted over, or over diligent scouring that erases the information. The information may never be changed or added to except as specifically directed by the cognizant bureau.

WEAPON SYSTEM COMPONENTS

It is not the intent of the following material to present all of the equipment with which you will come in contact; but to acquaint you with the overall function of the different categories of equipment which make up a weapon system.

Detection and Identification Equipment - The first steps in the functioning of a weapon system are detection, location, and identification. In the early history of naval warfare, it was sufficient to rely upon visual means. With the advances made in modern warfare, it has become necessary to accomplish these steps at maximum range, with maximum accuracy, and with minimum delay. The principle detecting devices (detecting will here include locating and identifying) now used in the fleet include: Optical devices, Radar, ECM (Electronic Countermeasures), Sonar, and MAD (Magnetic Detection).

Optical devices in weapon systems function to establish target bearing and (for air targets) target elevation. Some optical devices, such as range finders, can also measure range. Optical devices are invariably passive (detect radiation emitted or reflected by the target, but do not produce the radiation they detect). Optical devices are normally restricted to line of sight and are dependent on visible light reflected by the target.

Radar (Radio Detection and Ranging) equipment is always an active device. Electromagnetic energy is radiated and some of the energy is reflected back from any target which falls within the radar beam. The reflected energy is used to provide some type of visible display on a CRT (Cathode Ray Tube) which can indicate range, bearing, and for some applications elevation. Radar, unlike optical equipment, does not depend on visible light. Radar does have the disadvantage of being jammed or interfered with by enemy radar transmissions and other countermeasures. For our purpose, radars may be grouped into two general categories --search radars and fire control radars. Fire control radars are considered as controlling devices.

Search radars may be classified according to their primary function. Surface search radars normally have relatively short ranges but provide quite accurate bearing information. They are normally used for detection of surface targets and for navigation, but can detect low-flying aircraft at short ranges. Air search radars are designed for long range detection. The bearing information is usually not as accurate as with surface search radars because of the width of the transmitted beam. Height finding radars were designed to determine the elevation of aircraft. With the advent of missile systems, another form of air search radar was developed. The use of missiles against aircraft requires early detection and maximum accuracy in the determination of range, bearing, and elevation. This type of radar is known as a three coordinate or 3D radar, also because of its primary application in weapon systems it is sometime referred to as a designation radar.

Because radar does not present a pictorial image of the target, some means of identification must be provided. IFF (Identification Friend or Foe) equipment is included as part of search radars. All of our friendly ships and aircraft will carry IFF equipment. This equipment is designed to automatically send out a coded radiation whenever a challenge is received in the form of radiated energy from the radar.

ECM (Electronic Countermeasures) are defined as the means by which our forces attempt to nullify advantages of enemy electronic devices, and to obtain all possible information concerning enemy electromagnetic radiation. ECM may be either active or passive.

Passive ECM are not detectable by the enemy. These measures are designed to detect and determine the source and characteristics of all electromagnetic radiations. From such analysis can be determined such information as the type of equipment radiating, what its function may be, and the number of transmitters involved. Other passive ECM methods are tactical evasion (to avoid detection by the enemy) and control of electromagnetic radiation by own ship (silence imposed on own ship's electronic transmitters) to avoid telltale radiation.

Active ECM includes methods to impair operation of enemy electronic devices by jamming and deception.

Sonar (Sound Navigation and Ranging) provides for detection of underwater targets. Sonar may be either active or passive. Active sonar utilizes pulses of ultrasonic sound energy in much the same manner as radar uses electromagnetic energy. Passive sonar detects underwater sounds emanating from the target.

MAD (Magnetic Detection) operates on the principle of detection of distortion of the earth's magnetic field by any ferrous object.

Delivery Devices - Examples of delivery devices are: guns, torpedo tubes, rocket launchers, projectors, depth charge racks, and missile launchers. The term weapon is with one major exception applied to the destructive unit that is launched, carried, or projected. Thus, a torpedo tube or rocket launcher is not the weapon, the torpedo or the rocket is the weapon. The major exception is the gun. The gun is normally called the weapon; a gun projectile is generally not called a weapon.

All weapons and projectiles must either be directed to their targets or target area, or programmed so they will operate properly in the target approach. They may require both directing and programming. This is done at or before launch either by or through the delivery device. For example: A gun is aimed to direct the projectile along the line of fire; missile launchers convey program instructions to the weapon either mechanically or electronically.

Weapons and Projectiles - The end purpose of a weapons system is to get the destructive unit to meet the target. It is the function of the destructive unit to destroy or inflict maximum damage on the target.

All weapons and projectiles have the following functional components, which may take different physical forms in different weapons: a container or body, a detonating device, and a burster. The body houses the components and may have other functions such as piercing armor, breaking up into high-velocity fragments, or (by its shape) improving ballistic characteristics. A detonating device (fuze, pistol, exploder, detonator, etc.) initiates the explosion at the proper time, and includes safety devices to prevent explosion prematurely. The burster or payload usually consists of an explosive. In addition to the preceding components, weapons such as guided missiles, torpedoes, and rockets have their own propulsion systems.

Control Units - Control units in a weapon system develop, compute, relay, and introduce data into a delivery unit, weapon, or both, in order to direct, control, or guide the weapon to the target and cause it to function in the desired way. GFCS (Gun Fire Control Systems), Torpedo Fire Control Systems, various Underwater Fire Control Systems, TDS (Target Designation Systems), and WDS (Weapon Direction Systems) all function as control units. As an FT, these are the equipments which will be your primary responsibility. In addition to these control units, the 3D radar and the missiles are also the responsibility of FTs.

REVIEW AND SUMMARY

A weapon system includes detection units, delivery units, control units, and destructive units. Fire control equipment may be identified by Mk and Mod or JAN nomenclature. Equipment nameplates provide the best primary source for identification of equipment.

TOPIC 2: CONTROL UNITS

YOU ARE NOW GOING TO LEARN:

1. The general classes of GFCS.
2. The types of relative rate GFCS.
3. The basics of GFCS Mk 63.
4. The basics of GFCS Mk 56.
5. The basic components of GFCS Mk 68.
6. The various types of missile guidance.
7. The function of TDS and WDS.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Gun Fire Control Systems.
    a. Linear rate.
    b. Relative rate.
        (1) Disturbed line of sight.
        (2) Undisturbed line of sight.
2. GFCS Mk 63.
3. GFCS Mk 56.
4. GFCS Mk 68.
5. Missile guidance.
    a. Command guidance.
    b. Beam rider guidance.
    c. Homing guidance.
6. TDS Mk 5.
7. WDS Mk 7.
8. Review and summary.

INFORMATION AND DISCUSSION:

GUN FIRE CONTROL SYSTEMS

Regardless of the type of fire control system or the target, the primary function of the system is to solve the fire control problem. The general steps are:

1. Determine present target position in relation to own ship.
2. Predict future target position in relation to own ship.
3. Stabilize the various units to compensate for ship's roll and pitch.
4. Calculate required corrections to train and elevation orders.
5. Transmit data to the delivery device.

There are two general classes of GFCS: Those which determine rates of change of relative target motion as linear rates (linear rate systems) and those which measure the angular velocity of the line of sight by gyroscopic means (relative rate systems).

In linear rate systems such as the Mk 37 and the Mk 68, the director measures target position in three coordinates: range, relative target bearing, and target elevation. A stable element is used to compensate for roll and pitch and a computer provides continuous gun positioning orders and fuze settings.

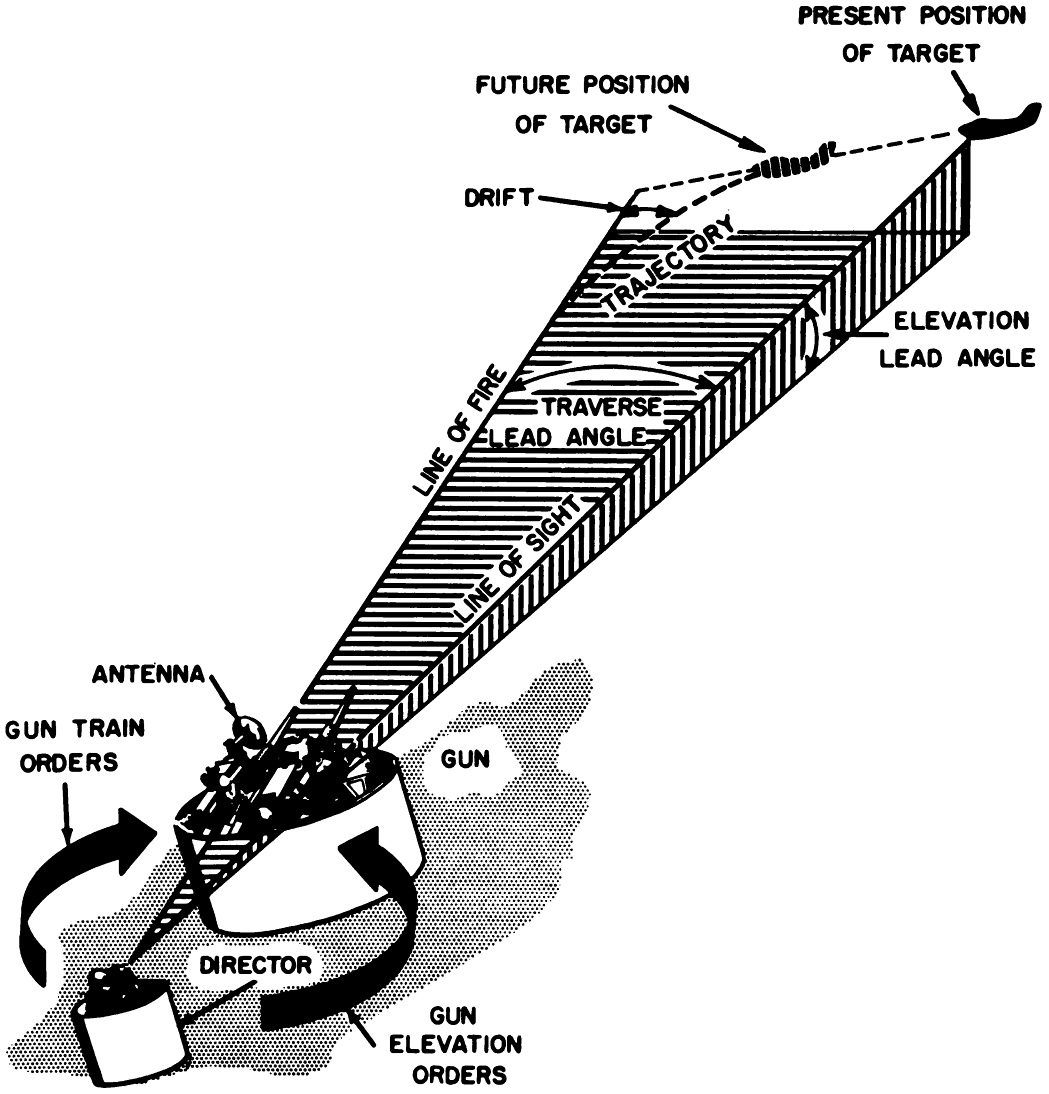
Relative rate systems are divided into two types: disturbed line of sight and undisturbed line of sight.

The basic characteristic of the disturbed line of sight system is that the line of sight is offset from the fore and aft axis of the sight case by the amount of computed lead angle so that the sight case itself is aligned with the gun bore axis. Most lead-computing sights are of this type. GFCS Mk 63 uses this type of sight.

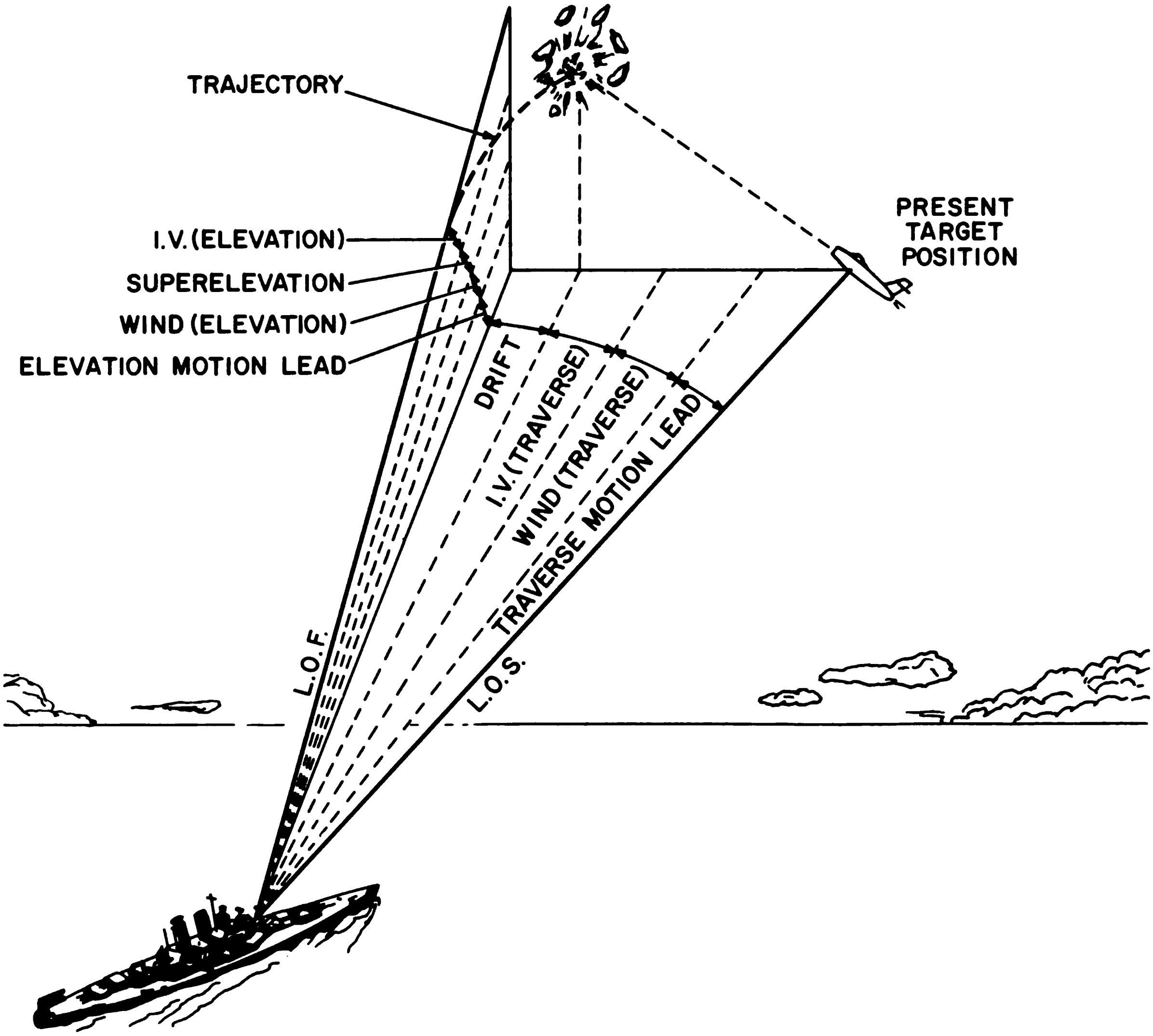
The basic characteristic of the undisturbed line of sight system is that the lead angles are measured and sent to a computer which makes up gun orders, while leaving the line of sight fixed in relation to the sight case. The Mk 56 is an example.

GFCS MK 63

The function of the Mk 63 is to provide train and elevation orders for positioning a gun so a projectile from that gun will hit a specific target. The illustration below shows the lead angles and the relationship between the line of sight and the line of fire.



34. LEAD ANGLES



35. LEAD ANGLE COMPONENTS

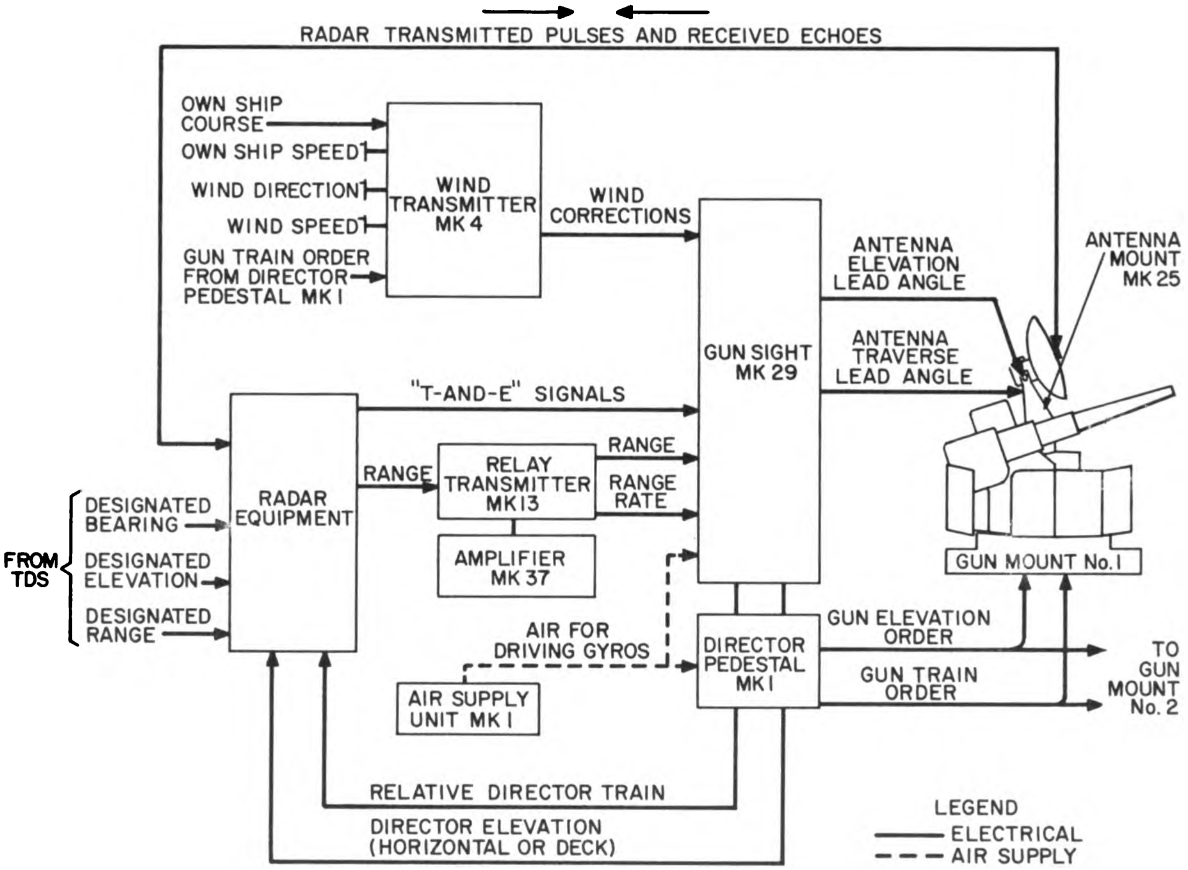
The illustration above shows the components of the lead angles. You can see that the lead angles are made up of various components. Drift, wind, initial velocity, relative motion, and gravity (introduced as superelevation) effects are resolved into horizontal and vertical components for development of the proper lead angles.

The illustration on the facing page is a simplified data flow diagram applicable to certain modifications of the Mk 63 GFCS.

The major components of the control system are: Director, Radar, Wind Transmitter, and Gunsight. The Mk 63 uses a handle-bar type director which is manually positioned in train and elevation by an operator. The target may be tracked optically or the radar may be used to generate a target symbol which the operator tracks in the same manner as an optical target. The operator tracks the target by keeping the gunsight telescope cross-hairs on the target. The gunsight, which contains rate gyros, computes the angular velocity of the target in both elevation and bearing. Gyroscopic action causes mirrors within the gunsight to be moved in such a manner that the line of sight is offset from the axis of the sight. Radar range information is applied to the gunsight where it is used to control the amount of movement of the mirrors due to gyroscopic action. The operation above has covered the first two steps in solving the fire control problem: to determine present target position and predict future target position. The next step, to stabilize the various units, is accomplished by the operator, as he keeps the cross-hairs on target, and a cross-roll gyro mounted in the director. The gunsight and the wind transmitter function together to calculate required corrections for gun train and elevation orders. The wind transmitter, which uses electro-mechanical computer devices, provides electrical inputs to torque motors in the gunsight. The torque motors affect the action of the gyros which in turn position the mirrors. The gunsight also contains a system of weights which affect gyro action to compensate for the effect of gravity and drift. Initial velocity corrections may also be set into the gunsight to affect the action of the gyros. At this time you need only to consider the gyro units within the gunsight as a computer. The last step in solving the fire control problem is to transmit data to the guns. A system of synchros is used to transmit director position to the guns. Director position leads the line of sight by the total lead angle and therefore represents gun orders for train and elevation.

GFCS MK 56

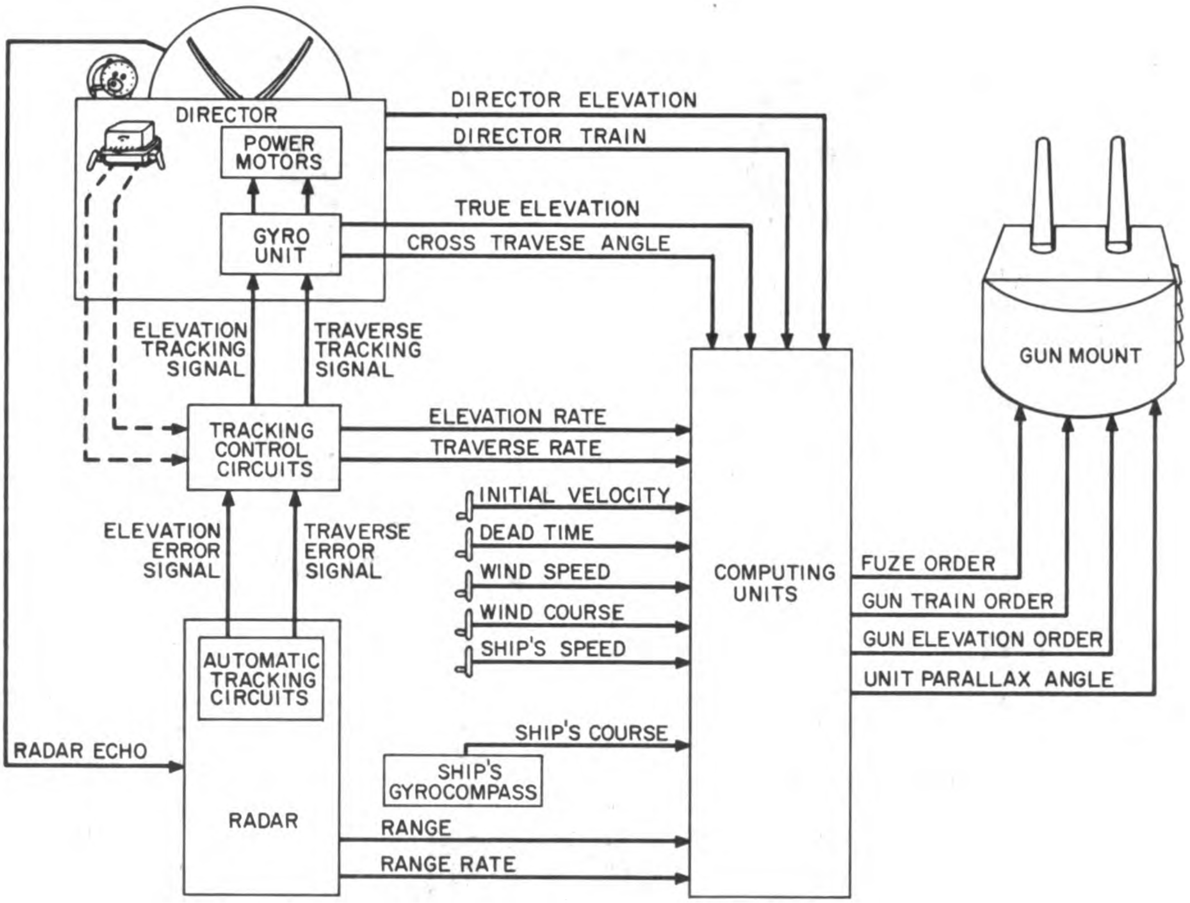
The Mk 56 was designed to provide gun train and elevation and fuze orders for 3, 5,



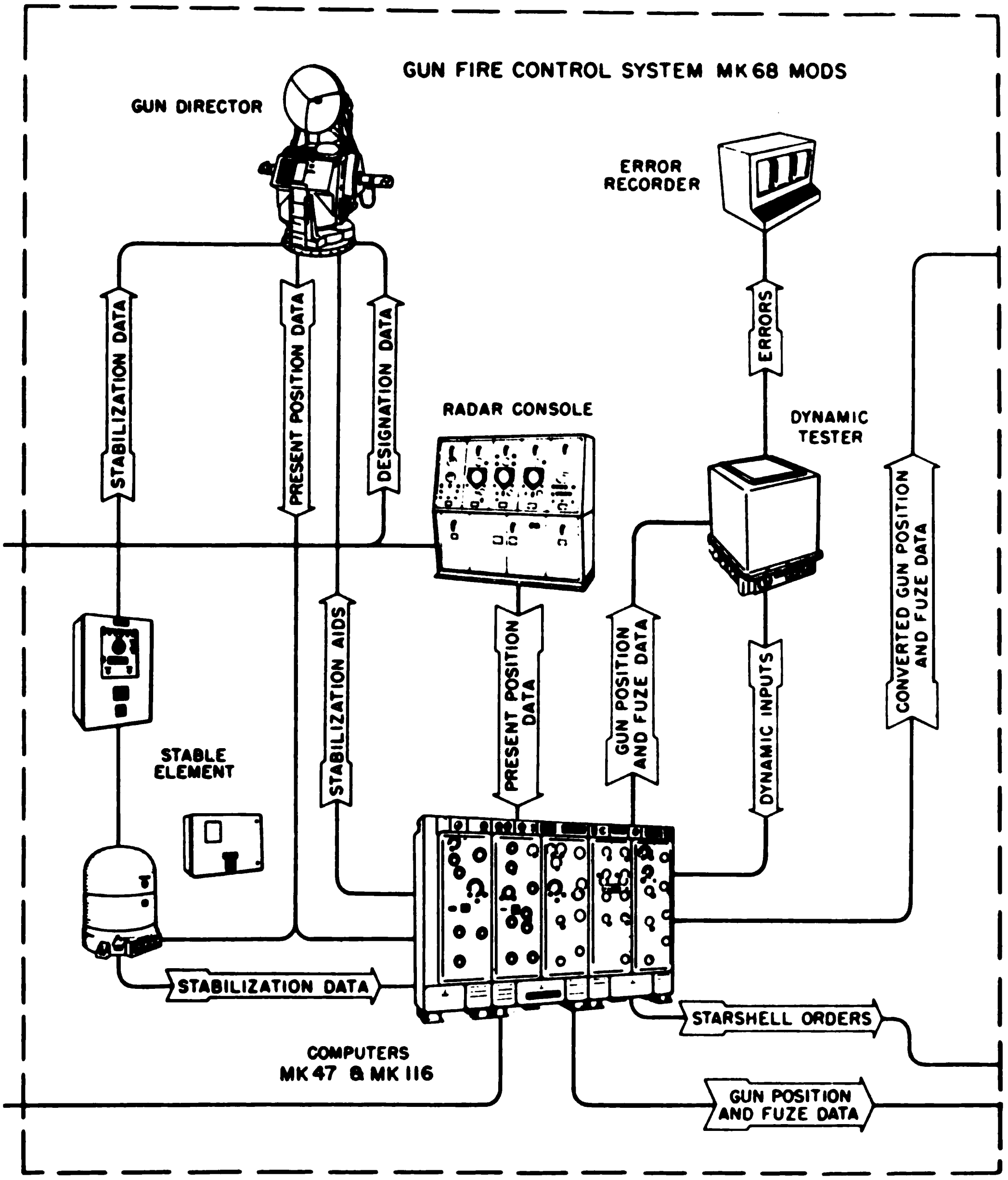
36. SIMPLIFIED FLOW DIAGRAM FOR GFCS MK 63 MODS 14 AND 16 THRU 22

and 6 inch guns. Because the system is capable of simultaneously producing gun orders for two different caliber guns, it is called a dual-ballistic system. It is also considered a dual-purpose system because it may be used against either air or surface targets.

The illustration on the facing page is a basic flow diagram of a Mk 56 GFCS. Major components of the system include: Director, Radar, Wind Transmitter, and two Computers. One computer handles ballistic calculations such as those necessary to compensate for gravity, drift, etc. The other computer combines the ballistic calculations with rates of target motion and converts the sum into lead angles. Tracking with the Mk 56 system can be either optical or radar. For optical tracking, a tracking control unit and a telescope are provided in the director. Rotation of a hand grip on the control unit provides electrical signals which control the director power drives. In automatic radar tracking, the tracking signals originate in the radar. The director line of sight is stabilized by a gyro unit. The gyro unit consists of a vertical gyro and a rate gyro. An elevation linkage between the radar antenna (mounted on the director) and the gyro unit maintains the main gyro gimbal axis parallel to the line of sight. The purpose of the vertical gyro is to establish stable reference planes. The vertical gyro measures E, elevation above horizontal plane, and Zs, cross-traverse angle. Cross-traverse differs from crosslevel Z in that it is measured in a plane perpendicular to the line of sight rather than in the vertical plane. Electrical signals representing E and Zs are sent to the computers for use in calculation of ballistic corrections and gun orders. Zs also goes to the cross-traverse drive gear of the rate gyro for stabilization. The rate gyro controls the drive motors which position the director in train and elevation. The gyro does this by measuring angular rates of target motion in the form of electrical signals and combining these signals with the stabilizing signals. Basically what happens is that tracking signals, from the radar or those generated by rotation of the handwheel in the director, operate torque motors which cause the gyro to precess (move according to gyroscopic principal). As the gyro precesses, electrical pick-off devices produce signals which control the director power drive to reposition the director. In this manner the director line of sight is made to follow the target. Synchros in the director transmit director position in train and elevation to the computing units. True elevation and cross-traverse angle data is sent to the computing unit from the gyro unit. With range supplied from the radar, the present position of the target is known. Since the director line of sight is kept on target by the tracking signals, these signals represent, and are sent to the computing units, as elevation rate and traverse rate. With the addition of range rate from the radar, future position may be determined. With the vertical gyro providing the stabilization, all that remains to solve the fire control problem is for the computer to calculate the corrections and transmit the gun orders.



37. SIMPLIFIED FLOW DIAGRAM - MK 56 GFCS



38. BLOCK DIAGRAM OF GFCS MK 68

GFCS MK 68

This system, shown in the illustration on facing page, is one of the Navy's most modern GFCS. The Mk 68 is a fully automatic system used to control the rapid fire 5"/54 caliber and 3"/70 caliber guns. It is designed for both surface and air targets. The gun director serves as the eyes of the system and provides present position of the target to the computer. The radar is used for automatic tracking. The radar supplies present range to the computer and angle error signals to the director power drives. The computer is the brain of the system. The computer provides gun orders for the 5" guns. The gun order converter is really another computer which converts the 5" gun orders to orders for a 3" gun. The star shell computer converts the 5" gun orders to 5" star shell orders. The stable element measures the roll and pitch of the ship and converts this to level and crosslevel which is sent to the computer and the director. The computational techniques used by the computer were demonstrated previously in solving the fire control problem.

MISSILE GUIDANCE

It is beyond the scope of this trainee's guide to present a detailed explanation of MFCS. Also, much of the data for missile systems is classified and therefore cannot be included. The fire control problem, however, remains basically the same. One major difference between missiles and gun projectiles is that the missile can be guided. Because the missile can be guided, the fire control system must be able to provide guidance information. This information may be in the form of control guidance signals or reference information, depending on the type of guidance used. With some forms of guidance, the fire control equipment used to provide guidance is actually located in the missile itself. As an introduction to MFCS, some of the principal systems of guidance are illustrated:

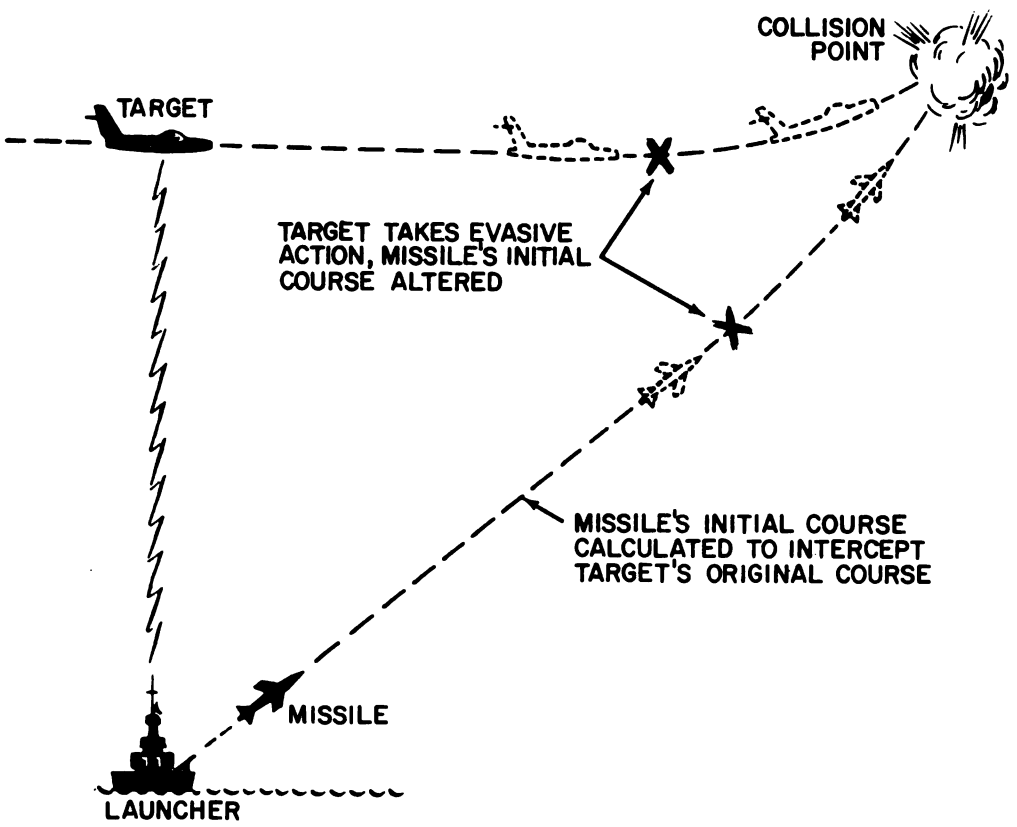
1. Pre-set gyro - A predetermined path is set into the missile prior to launching and cannot be altered in flight. A programmer activates components within the missile to perform certain functions, such as course change, as the missile proceeds along its flight path.

2. Terrestrial reference - Phenomenon related to the earth, such as air density, is used to adjust a predetermined path.

3. Inertial - A predetermined path is adjusted by devices, such as accelerometers, within the missile.

4. Celestial - The known apparent position of celestial bodies is used as a reference. The predetermined path is adjusted by continuous celestial navigation.

5. Radio navigation - External radio signals are used to alter a predetermined path. The simplest method is one in which a directional antenna in the missile is used to maintain predetermined bearings with respect to two radio transmitters.

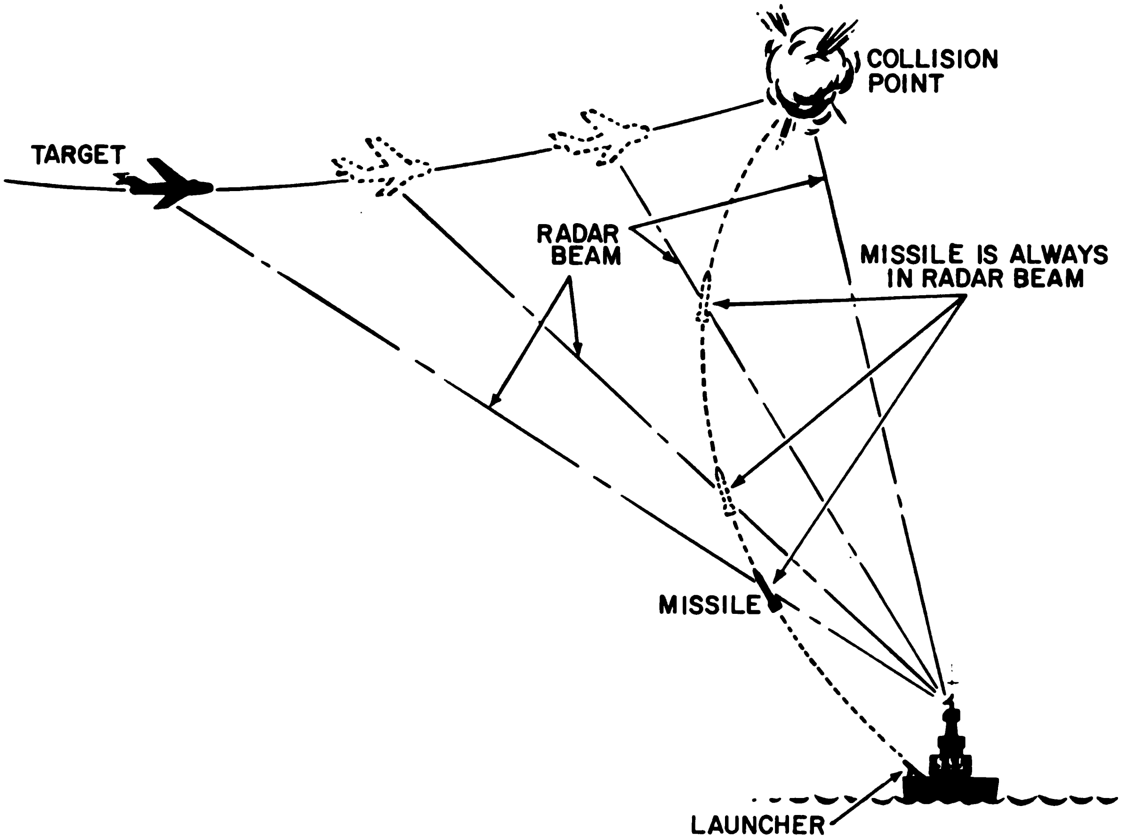

COLLISION POINT
TARGET
TARGET TAKES EVASIVE ACTION, MISSILE'S INITIAL COURSE ALTERED
MISSILE'S INITIAL COURSE CALCULATED TO INTERCEPT TARGET'S ORIGINAL COURSE
MISSILE
LAUNCHER

39. COMMAND GUIDANCE

6. Command guidance - The illustration above illustrates command guidance. Target position and motion data are received by the guidance control station and the missile is launched along a path to intercept the target. Target position is continuously monitored and orders transmitted to the missile to alter its flight path.

7. **Beam rider** - In this type of guidance, shown in the illustration below, the control station uses radar to track the target. The missile contains equipment to detect the radar beam and follows the center of the beam to the target.

8. **Homing guidance** - In this type of guidance, the missile seeks out and



40. BEAM RIDER GUIDANCE

pursues the target, guided by some indication from the target itself. Radar or sound wave reflections, optical, magnetic, or heat indications are possible influences upon which homing systems may be based. The illustrations on the facing page illustrate that homing systems may be classified according to the angle of attack as direct homing or lead angle homing. Homing systems are also classified according to the way the guidance signals are received by the missiles homing mechanism. Passive homing is the case where the target provides the source of homing information. This may be in the form of heat, sound, etc. Semi-active homing relays on some externally supplied form of energy being reflected from the target. As an example: Radar energy from a tracking station is beamed at the target and some of the energy reflected is detected by equipment in the missile and used to provide guidance information. Active homing is similar to semi-active except the source of energy, such as radar, is carried in the missile itself.

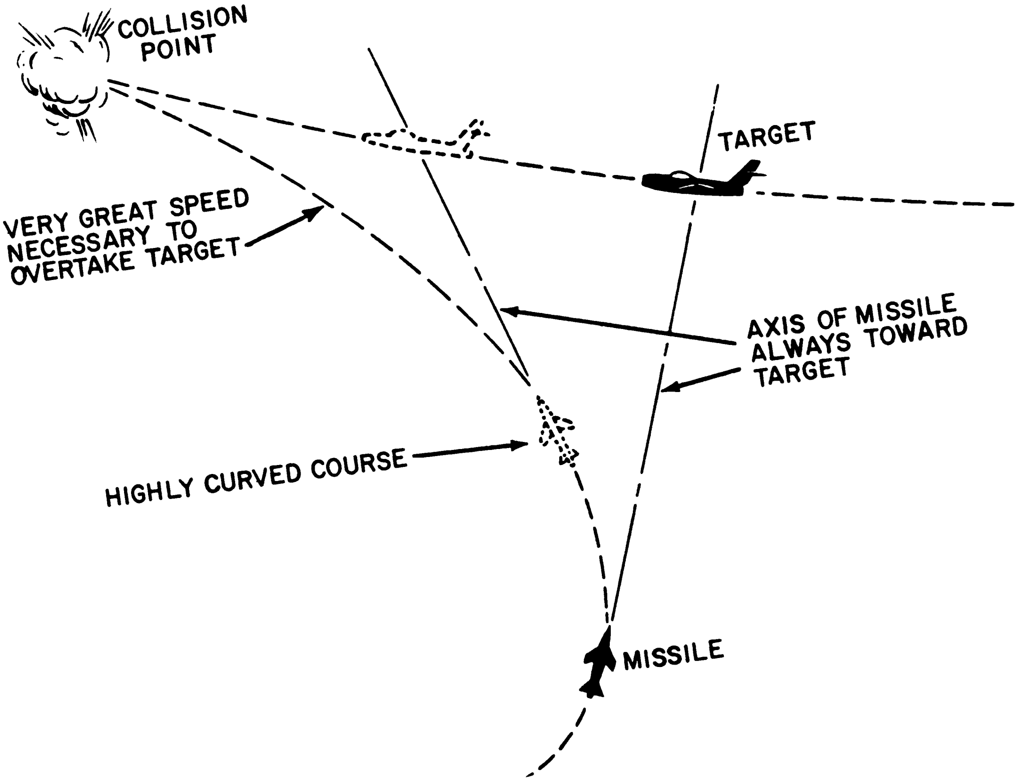
Major missiles presently in use by the Navy include Tartar, Terrier, Talos, and Polaris.

Tartar is a single-stage, solid fuel rocket propelled, supersonic, surface-to-air, anti-aircraft guided missile using tail control and semi-active homing. The shipboard equipment of the Tartar missile system includes search radar, tracking and illuminating radar, computer, launcher, and weapons direction system.

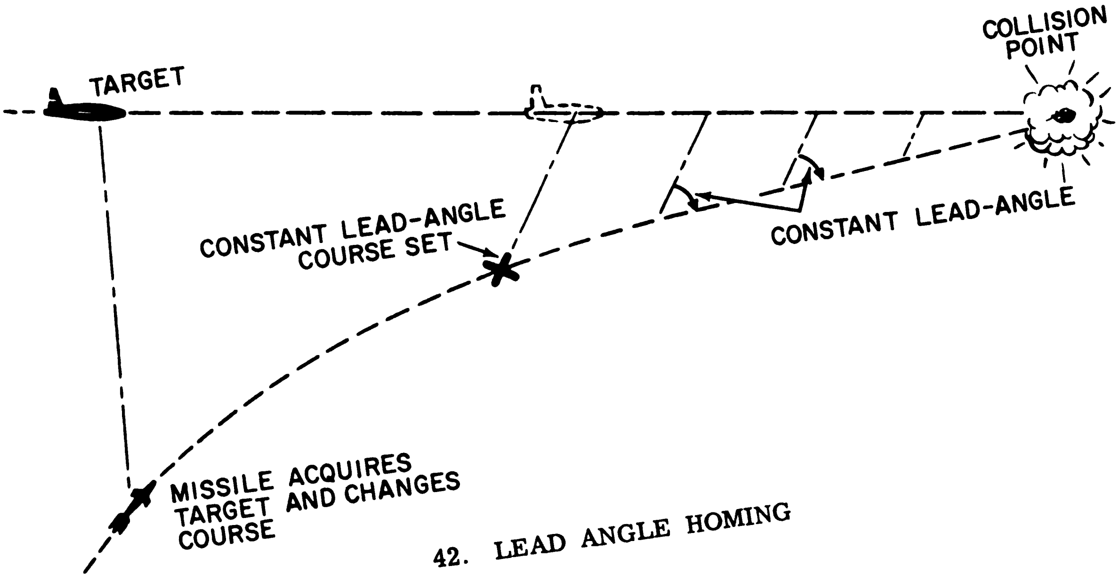
Terrier is a two stage, supersonic, surface-launched, anti-aircraft guided missile which uses a solid-fuel rocket booster and a solid-fuel sustainer. There are both beam rider and homing type Terrier missiles. Shipboard equipment includes a search radar, guidance radar, computer, launcher, and weapons direction system.

Talos is a long range, supersonic, surface-to-air guided missile designed to intercept and destroy enemy aircraft flying at high altitude and supersonic speed. Talos uses a solid-fuel booster and a ramjet propelled sustainer. Beam rider guidance is used during the midcourse phase of the trajectory and semi-active radar homing in the terminal phase.

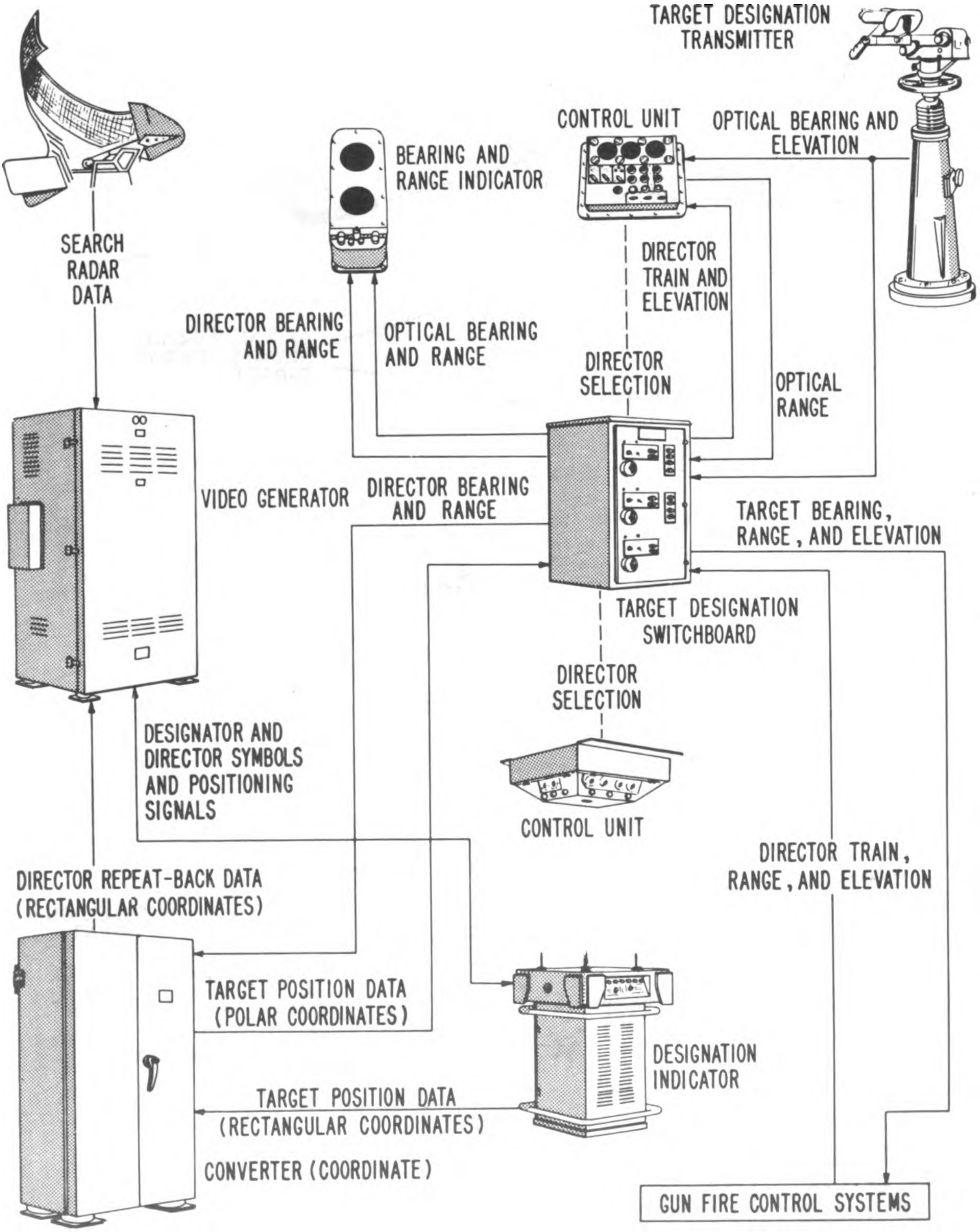
Polaris is a 1500-mile-range missile designed for use against shore installations. It can be launched from a submarine, either submerged or surfaced. It is a two-stage, solid propellant missile using inertial guidance.


COLLISION POINT
TARGET
VERY GREAT SPEED NECESSARY TO OVERTAKE TARGET
AXIS OF MISSILE ALWAYS TOWARD TARGET
HIGHLY CURVED COURSE
MISSILE

41. DIRECT HOMING


TARGET
COLLISION POINT
CONSTANT LEAD-ANGLE COURSE SET
CONSTANT LEAD-ANGLE
MISSILE ACQUIRES TARGET AND CHANGES COURSE

42. LEAD ANGLE HOMING


TARGET DESIGNATION TRANSMITTER
CONTROL UNIT
OPTICAL BEARING AND ELEVATION
BEARING AND RANGE INDICATOR
SEARCH RADAR DATA
DIRECTOR TRAIN AND ELEVATION
DIRECTOR BEARING AND RANGE
OPTICAL BEARING AND RANGE
DIRECTOR SELECTION
OPTICAL RANGE
VIDEO GENERATOR
DIRECTOR BEARING AND RANGE
TARGET BEARING, RANGE, AND ELEVATION
TARGET DESIGNATION SWITCHBOARD
DIRECTOR SELECTION
DESIGNATOR AND DIRECTOR SYMBOLS AND POSITIONING SIGNALS
CONTROL UNIT
DIRECTOR TRAIN, RANGE, AND ELEVATION
DIRECTOR REPEAT-BACK DATA (RECTANGULAR COORDINATES)
TARGET POSITION DATA (POLAR COORDINATES)
DESIGNATION INDICATOR
TARGET POSITION DATA (RECTANGULAR COORDINATES)
CONVERTER (COORDINATE)
GUN FIRE CONTROL SYSTEMS

43. TDS MK 5 - DATA FLOW

TDS MK 5

You may recall an earlier mention of Target Designation Systems (TDS). These systems were designed to coordinate the assignment of gun directors to specific targets. What the TDS does is to:

1. Present a complete picture of the air defense situation on which decisions can be based.
2. Enable target assignment to be made as automatically as possible, with minimum of delay, with maximum of accuracy, and with a positive indication that the director has engaged the designated target.

TDS Mk 5, shown in the illustration on the facing page is an example of such a system. Target position data may be fed into the TDS from search radar or from optical tracking equipment. Search radar information is presented on a plan position indicator (PPI) in combat information center (CIC). The operator views this visual display and determines which targets should be assigned to which gun directors. By operating controls on the designation indicator, the operator transmits target position data in rectangular coordinates to a converter which changes the data to polar coordinates. The data from the coordinate converter is transmitted through a target designation switchboard to the selected director or directors. The gun director is trained and elevated and the range gate is positioned to the designated area. This method of designation permits the director to rapidly lock on and commence tracking the selected target. Information from the director back to the PPI lets the designation operator know the director is tracking the target. Opitcal input is from a target designation transmitter through a control unit and the switchboard to the gun director. Director position is fed back to a bearing and range indicator.

WDS MK 7

With the advent of the missile as a weapon, the coordination problem was further amplified. The concept of coordination became more than just designation, and a new series of Weapon Direction Systems were developed. WDS, as the name implies, provide direction for the entire weapon system. The WDS performs the same function as TDS and much more. To illustrate WDS, and also to present the data flow for an entire weapon system, the WDS Mk 7 has been selected.

The illustration on the facing page shows the weapon system for a DLG-16 class frigate. The various equipments may often be classified as follows:

1. Search Radars and IFF
    a. Three coordinate
    b. Surface search
    c. Air search
2. Terrier Weapon System
    a. Missile Fire Control System
        (1) Radar
        (2) Computer
    b. Missile Launching System
    c. Terrier Missiles
3. Gun Fire Control System
    a. Director
    b. Radar
    c. Guns
4. Underwater Battery
    a. Underwater Fire Control System
    b. ASROC Launcher
    c. ASROC Missiles
5. Weapon Direction System
    a. Weapon Direction Equipment
    b. Target Designation Transmitters
    c. Associated Equipment

You will remember, as stated previously, a weapon system consists of the following:

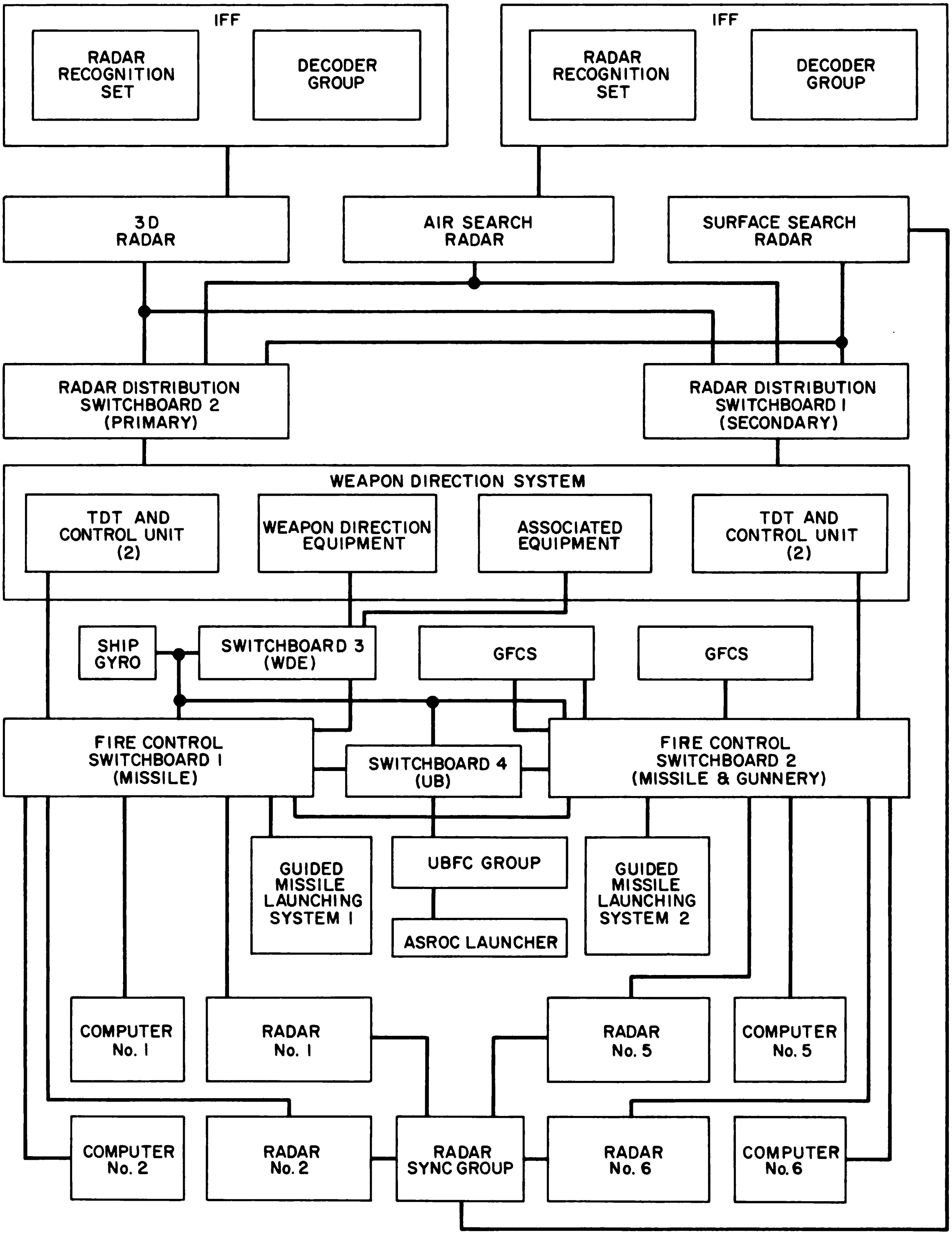
1. Units which detect, locate, and identify.
2. Units which initiate delivery of the destructive unit.
3. Units that control a delivery unit.
4. Destructive units.

You can see that search radar and IFF, as well as the sonar associated with UB, are the detection units. The guns, missile launching systems, and ASROC launcher are delivery units. The Terrier and ASROC missiles and the gun projectiles are the destructive units. The control units are the GFCS, MFCS, WDS, and underwater fire control system.

You will also notice the ship's gyro and various switchboards which are also part of the weapon system. Each component has a definite relationship to the system and all must function together to provide an effective weapon system.

The purpose of WDS Mk 7 is to coordinate and direct the use of the missile and gun systems of the DLG-16 class ships. WDS Mk 7 is used to evaluate relative target threat, assign fire control systems to the most threatening targets, and control the firing of missiles.

Weapon Direction Equipment (WDE) Mk 4 is the major component of WDS Mk 7. In WDS Mk 7, the optical designators (TDTs) are the primary source of designation to gun systems and secondary source of designation to missile systems. WDE designations may be either to gun or missile systems. For purposes of illustration, only missile targets will be considered in the discussion which follows.



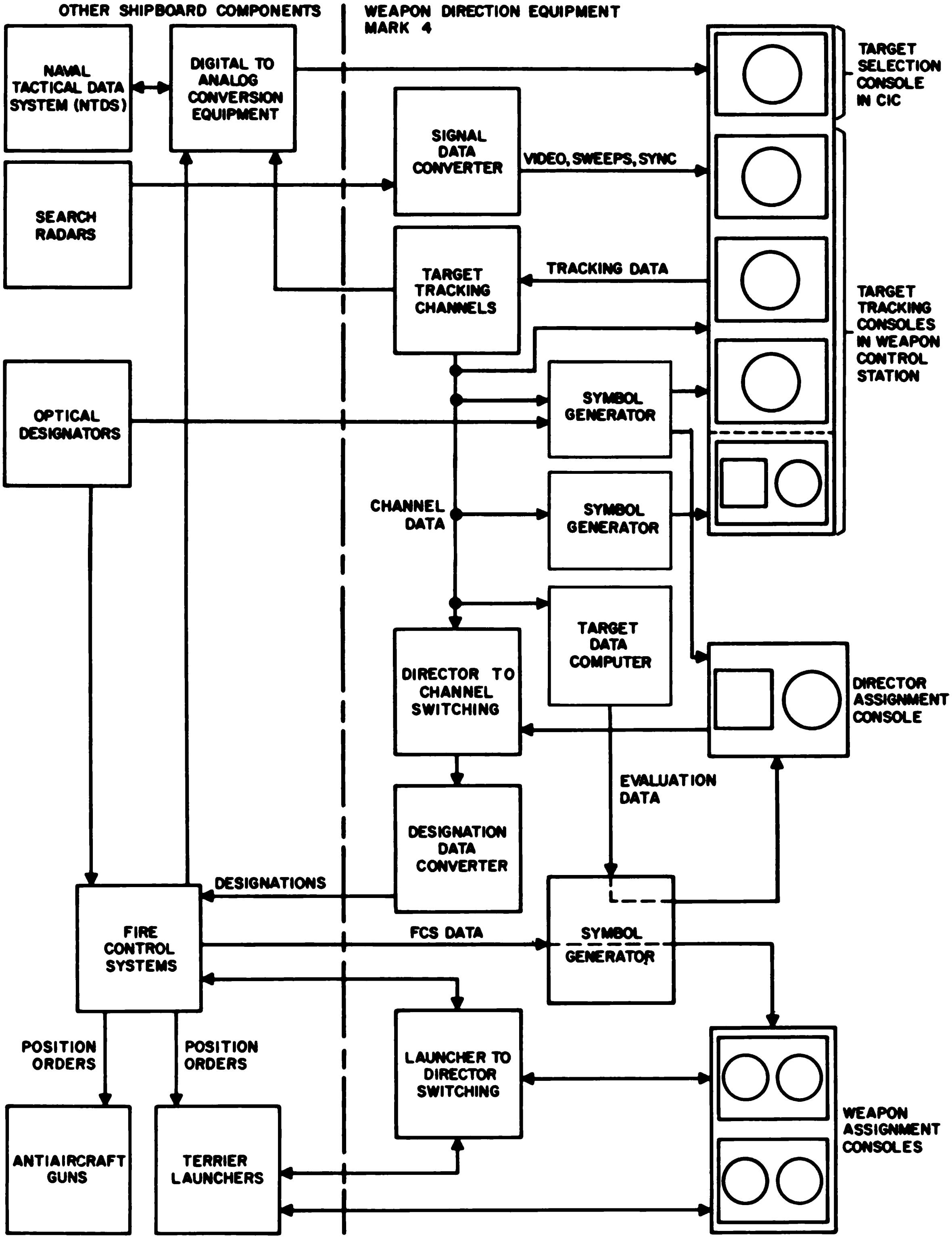
44. BLOCK DIAGRAM OF WEAPON SYSTEM FOR DLG-16 CLASS SHIPS

With reference to the illustration on the facing page, target position data is supplied to WDE from several possible sources. The input may be from one of the ship's three search radars or from Naval Tactical Data System (NTDS). This position data is converted to the signals necessary to make up a PPI display for WDE. This data in the form of video, sweep, and synchronization signals, provides visual displays on a Target Selection Console (TSC), three Target Tracking Consoles (TTCs), and a Height Tracking Console (HTC). The TSC operator, under supervision of CIC officer, assigns the target to one of eight tracking channels and the HTC operator allocates the channel to one of the three TTCs. The TTC operator uses controls on his console to track the target video. Updated position data is electronically transmitted and stored in target tracking channels. An electronic symbol system within WDE utilizes the tracking channel information to present visual displays of certain symbols associated with the target. At the same time the TTC operator is tracking the target to provide range and bearing information, the HTC operator is tracking the target in elevation. The HTC data is also transmitted to the tracking channels. As many as eight targets may be tracked simultaneously. The tracking channel information, in symbol form, is displayed on a Director Assignment Console (DAC) PPI display. A target data computer uses tracking channel information to generate symbols for another type of display on the DAC. The information on this display includes target height, speed, and indication of the time remaining before a director may be assigned for maximum effectiveness, and the latest possible time for assigning the target to a missile system. The DAC operator (usually an officer) uses the display information to evaluate the targets. The four most threatening targets may then be assigned to MFCS. The DAC operator uses controls on his console to transmit designation data through a switching system and data converters to the four MFCS. The MFCS automatically slew to the designated coordinates and lock on to the target. As the MFCS tracks the target, the information from two of the MFCS is displayed on one Weapon Assignment Console (WAC) and information from the other two on a second WAC. The WAC operator (always an officer) evaluates the information which includes present and future position, and determines which of the two targets is the most threatening. The WAC operator, under supervision of the Weapons Control Officer, uses switches to select the type of missile to be used (beam rider or homing), the type of salvo to be fired etc. Personnel in the launching area initiate the loading of the launcher in response to the signals from WDE. The WAC operator then assigns the launcher to the MFCS tracking the most threatening target. The assignment, made through switching circuits, connects the launcher to the MFCS and the launcher slews to the desired position in response to orders from the MFCS. Information from the MFCS is fed into the missile and indications of ready to fire are transmitted from the launching system to the WAC. The WAC operator uses his display to determine the proper firing time and closes a firing key to activate firing of the missile. Once the missile or missiles have been fired, the MFCS continues to track the target and guide the missile to intercept and destroy the target.

REVIEW AND SUMMARY

GFCS may be classified as linear or relative rate systems. Relative rate systems may be further divided into disturbed line of sight and undisturbed line of sight systems. The Mk 63 is an example of a disturbed line of sight system. Gyros are used to measure angular velocities of a target and develop lead angles for the guns. The Mk 56 is an example of an undisturbed line of sight system. Gyros are used to measure angular rates of target motion and provide electrical signals to drive the director so as to track the target. A computer uses information from the director to compute gun orders. The Mk 68 is an example of a linear rate system. The radar and director provide target position information in range, bearing, and elevation and the computer computes gun orders.

There are various systems of missile guidance. Those of most concern to you are beam rider and homing. Homing guidance may be either direct homing or lead angle homing. Homing guidance may also be classified as active, semi-active, or passive.


OTHER SHIPBOARD COMPONENTS
WEAPON DIRECTION EQUIPMENT MARK 4
NAVAL TACTICAL DATA SYSTEM (NTDS)
DIGITAL TO ANALOG CONVERSION EQUIPMENT
TARGET SELECTION CONSOLE IN CIC
SIGNAL DATA CONVERTER
SEARCH RADARS
VIDEO, SWEEPS, SYNC
TARGET TRACKING CHANNELS
TRACKING DATA
TARGET TRACKING CONSOLES IN WEAPON CONTROL STATION
OPTICAL DESIGNATORS
SYMBOL GENERATOR
CHANNEL DATA
SYMBOL GENERATOR
TARGET DATA COMPUTER
DIRECTOR TO CHANNEL SWITCHING
DIRECTOR ASSIGNMENT CONSOLE
EVALUATION DATA
DESIGNATION DATA CONVERTER
DESIGNATIONS
FIRE CONTROL SYSTEMS
FCS DATA
SYMBOL GENERATOR
POSITION ORDERS
POSITION ORDERS
LAUNCHER TO DIRECTOR SWITCHING
WEAPON ASSIGNMENT CONSOLES
ANTIAIRCRAFT GUNS
TERRIER LAUNCHERS

45. BLOCK DIAGRAM OF WDE OPERATION

A TDS or a WDS functions to coordinate and control a weapons system.

To conclude this first two weeks, the following memorandum is included.

From: Staff, FT "A" School

To: All Trainees

Subject: Will You Be a Good FT?

Many of you profess a desire to be a good FT. How would you describe such a man? Of course there are many terms and phrases that could apply. We like to think of a good FT as a proud man, who is at the same time humble. Because this may sound strange, we will explain. A good FT has pride in his ability to diagnose and correct deficiencies in the complex equipment under his care. He is proud of the hard work and study that has made him a capable technician, and of his capacity to increase his proficiency. He is at the same time humble. Although he may have vast knowledge and experience in his field of work, he realizes that there is much that he does not know; that the day-to-day challenges of our work demand the very best of every one of us. In his humility, he also has respect for the capabilities and responsibilities of others, not only in fire control, but in other ratings as well.

A good FT realizes his responsibilities, both to his equipment and to his shipmates. He is aware of some of the opportunities that lie ahead for him. He also has developed self-confidence, knowing that if he adequately prepares himself he will be ready and able to do the job when an unforseen opportunity presents itself.

Many of us in the staff have had the pleasure of knowing and working with a great number of FT's who fit the above description. Certainly many of our instructors are in this category. We have also known some who were sadly lacking in the desired qualities. In between the top men and the least qualified, is a wide range of FT's with varying degrees of ability and potential for new and greater responsibilities. WHAT KIND OF AN FT ARE YOU GOING TO BE?

QUIZ:

1. What does the Mk number stand for in Radar Mk 25 Mod 3?

2. What does the Mod number stand for in the above example?

3. Under the JAN system of identification a Radar set is listed as AN/SPG-51B. What type of information is conveyed by each of the following:

   AN/

   S

   P

   G

   51

   B

4. Why are nameplates used on all Fire Control equipments?

5. What are the two classifications of ECM?

6. What are the two general classifications of GFCS?

7. Relative rate systems may be divided into what two types?

8. What does the director of GFCS Mk 68 provide to the computer?

9. What are the two types of guidance used on the Navy's surface to air missiles?

10. What is the difference between Active and Semi-Active homing?

11. Looking back on the first two weeks, why is it so important for you to think "SYSTEM"?

TABLE OF TRIGONOMETRIC FUNCTIONS

Angle	Sine	Cosine	Tangent	Angle	Sine	Cosine	Tangent
0	0.000	1.000	0.000	45	0.707	0.707	1.0000
1	0.017	0.999	0.017	46	0.719	0.694	1.0355
2	0.034	0.999	0.034	47	0.731	0.682	1.0724
3	0.052	0.998	0.052	48	0.743	0.669	1.1106
4	0.069	0.997	0.069	49	0.754	0.656	1.1504
5	0.087	0.996	0.087	50	0.766	0.642	1.1918
6	0.104	0.994	0.105	51	0.777	0.629	1.2349
7	0.121	0.992	0.122	52	0.788	0.615	1.2799
8	0.139	0.990	0.140	53	0.798	0.601	1.3270
9	0.156	0.987	0.158	54	0.809	0.587	1.3764
10	0.173	0.984	0.176	55	0.819	0.573	1.4281
11	0.190	0.981	0.194	56	0.829	0.559	1.4826
12	0.207	0.978	0.212	57	0.838	0.544	1.5399
13	0.225	0.974	0.230	58	0.848	0.529	1.6003
14	0.241	0.970	0.249	59	0.857	0.515	1.6643
15	0.258	0.965	0.267	60	0.866	0.500	1.7321
16	0.275	0.961	0.286	61	0.874	0.484	1.8040
17	0.292	0.956	0.305	62	0.882	0.469	1.8807
18	0.309	0.951	0.324	63	0.981	0.454	1.9626
19	0.325	0.954	0.344	64	0.898	0.438	2.0503
20	0.342	0.939	0.364	65	0.906	0.422	2.1445
21	0.358	0.933	0.383	66	0.913	0.406	2.2460
22	0.374	0.927	0.404	67	0.920	0.390	2.3559
23	0.390	0.920	0.424	68	0.927	0.374	2.4751
24	0.404	0.913	0.445	69	0.933	0.358	2.6051
25	0.422	0.906	0.466	70	0.939	0.342	2.7475
26	0.438	0.898	0.487	71	0.945	0.325	2.9042
27	0.454	0.891	0.509	72	0.951	0.309	3.0777
28	0.469	0.882	0.531	73	0.956	0.292	3.2709
29	0.484	0.874	0.554	74	0.961	0.275	3.4874
30	0.500	0.866	0.577	75	0.965	0.258	3.7321
31	0.515	0.857	0.600	76	0.970	0.241	4.0108
32	0.529	0.848	0.624	77	0.974	0.225	4.3315
33	0.544	0.838	0.649	78	0.978	0.207	4.7046
34	0.559	0.829	0.674	79	0.981	0.190	5.1446
35	0.573	0.819	0.700	80	0.984	0.173	5.6713
36	0.587	0.809	0.726	81	0.987	0.156	6.3138
37	0.601	0.798	0.753	82	0.990	0.139	7.1154
38	0.615	0.788	0.781	83	0.992	0.121	8.1443
39	0.629	0.777	0.809	84	0.994	0.104	9.5144
40	0.642	0.766	0.839	85	0.996	0.087	11.430
41	0.656	0.754	0.869	86	0.997	0.069	14.301
42	0.669	0.743	0.900	87	0.998	0.052	19.081
43	0.682	0.731	0.932	88	0.999	0.034	28.639
44	0.694	0.719	0.965	89	0.999	0.017	57.290
45	0.707	0.707	1.000	90	1.000	1.000	

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CODE OF CONDUCT

FOR MEMBERS OF THE ARMED FORCES OF THE UNITED STATES

THE CODE

I

I am an American fighting man. I serve in the forces which guard my country and our way of life. I am prepared to give my life in their defense.

II

I will never surrender of my own free will. If in command I will never surrender my men while they still have the means to resist.

III

If I am captured I will continue to resist by all means available. I will make every effort to escape and aid others to escape. I will accept neither parole nor special favors from the enemy.

IV

If I become prisoner of war, I will keep faith with my fellow prisoners. I will give no information nor take part in any action which might be harmful to my comrades. If I am senior, I will take command. If not, I will obey the lawful orders of those appointed over me and will back them up in every way.

V

When questioned, should I become a prisoner of war, I am bound to give only name, rank, service number, and date of birth. I will evade answering further questions to the utmost of my ability. I will make no oral or written statements disloyal to my country and its allies or harmful to their cause.

VI

I will never forget that I am an American fighting man, responsible for my actions, and dedicated to the principles which made my country free. I will trust in my God and in the United States of America.

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